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CHATHAM RISE PHOSPHORITE PROJECT

Technical Report on the Chatham Rise Phosphorite Project, New Zealand – Report for NI 43-101

Report prepared for:

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Acronyms and Abbreviations

%	per cent	Mt	million tonnes
AIM	Alternative Investments Market	NIWA	National Institute of Water and Atmospheric Research (New Zealand)
ATNAV	acoustic transponder navigation	NZD	New Zealand Dollar
BGR	German Federal Institute for Geosciences and Natural Resources	NZIER	New Zealand Institute of Economic Research
Boskalis	Boskalis Offshore Subsea Contracting B.V.	NZOI	New Zealand Oceanographic Institute
°C	degrees Celsius	NZPM	New Zealand Petroleum and Minerals
CRP	Chatham Rock Phosphate Ltd	NZX	New Zealand Stock Exchange
cm	centimetres	SATNAV	satellite navigation
CM Act	Crown Minerals Act	SO	<i>RV Sonne</i>
CMA ACT	Crown Minerals Amendment Bill	t	tonnes
CPT	Cone penetration test	TI	<i>MV Tranquil Image</i>
CRL	CRL Energy Ltd	TSX.V	Toronto Venture Stock Exchange
CSA	Continental Shelf Act	PEA	Preliminary Economic Assessment
DMC	Decision Making Committee (of the EPA)	ROV	Remotely operated underwater vehicle
EEZ	Exclusive Economic Zone	RSC	RSC Mining and Mineral Exploration
EIA	Environmental Impact Assessment	USD	United States of America dollar
EPA	Environmental Protection Authority	VA	<i>RV Valdivia</i>
DD	<i>RV Dorado Discovery</i>	XRF	X-ray fluorescence
DSIR	New Zealand Department of Scientific and Industrial Research		
GM	Global Marine		
Golder	Golder Associates Ltd		
JBL	JBL Exploration NZ Ltd		
Kenex	Kenex Knowledge Systems Ltd		
kg	kilograms		
kg/m ²	kilograms per square metre		
kg/m ³	kilograms per cubic metre		
km	kilometres		
kt	kilotonnes		
L	litres		
MPa	megapascals		
m	metres		
Ma	million years		
mm	millimetres		

Major Chemical Elements

Al ₂ O ₃	Aluminium oxide
CaO	Calcium oxide
F	Fluorine
Fe ₂ O ₃	Iron oxide
K ₂ O	Potassium oxide
MgO	Magnesium oxide
Na ₂ O	Sodium oxide
P ₂ O ₅	Phosphate pentoxide
SiO ₂	Silica dioxide
SO ₃	Sulphur trioxide
TiO ₂	Titanium oxide

Trace elements

As	Arsenic
Ba	Barium
Cd	Cadmium
Ce	Cerium
Co	Cobalt
Cu	Copper
Mo	Molybdenum
Ni	Nickel
Pb	Lead
Rb	Rubidium
Sr	Strontium
Th	Thorium
U	Uranium
V	Vanadium
Y	Yttrium
Zn	Zinc
Zr	Zircon

1. Summary

Chatham Rock Phosphate Limited (CRP) commissioned RSC Consulting Ltd (RSC) to prepare an independent technical report (the Report) in compliance with National Instrument 43-101: *Standards of Disclosure for Mineral Projects* (NI 43-101) and Form 43-101F1, in respect of the Chatham Rise Phosphorite Project (the Project) within New Zealand's Exclusive Economic Zone (EEZ) in the Pacific Ocean, ~450 km southeast of Wellington, New Zealand. The Project comprises one mining permit (MP) 55549, which is wholly owned by CRP. This Report documents material data and data collection procedures for the Project, has an effective date of 29 April 2026, and reports a Mineral Resource Estimate (MRE) for the Project.

1.1 Property Description & Ownership

The Project is located in the Pacific Ocean, ~450 km southeast of Wellington, within New Zealand's Exclusive Economic Zone, on New Zealand's Continental Shelf. The Project comprises MP 55549, which covers an area of 820 km² where seabed phosphorite nodules are present on the seafloor at a depth of ~350–450 m.

MP 55549 was granted on 6 December 2013 for a period of 20 years. In 2014, CRP lodged an application for a marine consent from the Environmental Protection Authority (EPA) that would allow CRP to mine phosphorite nodules. The application was rejected in February 2015, and no mining operations have commenced at the Project.

CRP previously held a prospecting licence (MPL 50270) covering the area adjacent to MP 55549. This licence was granted on 25 February 2010 and covered an initial area of 3,905 km², which included the area now held under MP 55549. A four-year extension was granted in 2014, covering a reduced area of 2,887 km². MPL 50270 was surrendered on 29 August 2019.

1.2 Geology & Mineralisation

The Project is located on the Permian–Triassic (300–200 Ma) Chatham Rise, which comprises a thick sequence of turbiditic sediments that were deposited in a subsiding trough on the Pacific margin of Gondwana. The phosphorite deposit occurs as a thin, surficial layer of phosphorite-bearing glauconitic sand with thicknesses typically ranging from 0–1 m on the seafloor at depths of ~350–450 m. The layer consists of typically of silt and sand-sized sediment, with phosphatised chalk nodules up to 15 cm in diameter. The Chatham Rise phosphorite comprises phosphorite nodules that are loosely distributed within a layer of Neogene glauconitic sand that typically measures ~20 cm thick but locally exceeds 1 m. The sand is a pelagic lag deposit comprising 20–40% silt and 30–60% fine-grained to very fine-grained sand, and the concentration of phosphorite nodules varies both vertically and laterally.

1.3 Exploration

Phosphorite nodules were first discovered on the Chatham Rise in the 1950s by a New Zealand Government survey. During the 1960s to 1980s several private and government sponsored cruises explored the Chatham Rise and surrounding seafloor

area. The most extensive surveys were conducted by an agreement between the New Zealand Department of Scientific and Industrial Research (DSIR) and the West Germany Government on cruises by the German research vessels *RV Valdivia* in 1978 and *RV Sonne* in 1981.

The 1978 *RV Valdivia* cruise was the first intensive sampling and research campaign to be conducted over the Chatham Rise; a total of 655 samples from 689 attempts were collected over a 300 km² area in the west of the Project area. Most of the samples were collected using a large Van Veen grab sampler of 0.12 m³ volume, weighing ~400 kg.

The 1981 *RV Sonne* cruise was the most comprehensive exploration effort to assess the Chatham Rise phosphorite deposit. In addition to oceanographic, meteorological and geophysical data, the cruise collected 19 hours of video recordings of the seafloor as well as 519 sediment samples taken by a pneumatic grab sampler. The seafloor sediment samples collected during this cruise are the most representative sample data collected on the Chatham Rise and the data are considered to be of sufficient quality to be included in an MRE.

Since acquiring the licence in 2010, CRP has conducted six cruises in two programmes in the Project area. The key task of the cruises was to validate the previous work conducted on the Chatham Rise and collect further geological, geotechnical, geophysical and environmental data. For phosphorite grade estimation purposes, the *MV Tranquil Image* cruise collected 55 samples using a Van Veen grab sampler. The *RV Dorado Discovery* conducted four cruises to the Project area and collected 206 box core and grab samples.

Sample quality and quality assurance and quality control (QA/QC) measures varied considerably between the cruises and within each cruise. A critical part of the assessment of the data collected in the Project area was to determine the quality thresholds to use to allow or disallow data to enter the MRE process. As part of the data verification process, the relative and absolute quality of the data was assessed by the Qualified Person (QP) in as much detail as practicable. The best samples were typically those that were collected using the pneumatic grab sampler, sampled the full sand horizon, had a small survey error and had no other apparent data biases. Samples collected from the *RV Sonne* are considered by the QP to represent the best quality samples collected in the Project area, followed by some of the *RV Valdivia* samples, and then the box core samples from the *RV Dorado Discovery*. Samples not included in the MRE are samples that suffered a technical failure during their collection, samples collected but which have no data recorded, samples with no location coordinates, non-validated data and samples documented as washed or otherwise biased.

1.4 Mineral Resource Estimate

Definition of the domains used for modelling was based on seismic facies delineated during the *RV Sonne* cruise. A two-dimensional (2D) block model was constructed, based on 1 km × 1 km blocks, that covers the sampled area based on the average data spacing in the main sample areas. A maximum search radius of 3,000 m was used, based on variogram modelling.

Estimation was performed in each domain using ordinary kriging, using the accumulation method on the parameters Ph kg/m² (phosphorite grade), depth (phosphorite thickness), and sample quality ranking (SQR). The grade (Ph kg/m³) was then calculated by dividing Ph kg/m² by the estimated depth for each block.

A total of 71 million cubic metres (m³) at an average grade of 295 kg/m³ Ph is classified as an Inferred Mineral Resource at a cut-off grade of 100 kg/m³ Ph (Table 1-1). There are no Mineral Resources that are classified in the Indicated or Measured categories. As the Chatham Rise phosphorite resource is classified entirely as Inferred, it does not constitute a Mineral Reserve and therefore does not have demonstrated economic viability. The specification of the phosphorite (i.e. the phosphate content) has been studied by various operators, including CRP, and determined to be ~18–19% P₂O₅ of screened material. The average thickness of the Mineral Resource is 0.20 m.

Table 1-1: Statement of Mineral Resources (phosphorite) for MP 55549, Chatham Rise, with an effective date of 29 April 2026. Estimates are rounded to reflect the level of confidence in these resources.

Classification	Volume (m ³)	Thickness (cm)	Grade (Ph kg/m ³)
Inferred	71,000,000	20	295

Notes:

1. The Mineral Resource is reported in accordance with CIM Definition Standards for Mineral Resources and Mineral Reserves (May 2014).
2. The MRE has an effective date of 29 April 2026.
3. The Mineral Resource is contained within MP 55549.
4. Estimates are rounded to reflect the level of confidence in these resources at the present time. All resources have been rounded to the nearest 0.1 million tonnes
5. Grade (Ph kg/m³) is the weight of phosphorite per cubic metre.
6. Contained Ph Mt is contained weight of phosphorite per million tonnes.
7. The specification of the phosphorite (i.e. the phosphate content) has been studied by various operators, including CRP, and determined to be ~18–19% P₂O₅ of screened material.
8. The Mineral Resource is reported at 100 kg/m³ phosphorite cut-off grade, calculated using a phosphate rock price of USD 150 per tonne based on prices from 2024 to 2026.
9. The Mineral Resource is classified entirely as Inferred. It does not constitute a Mineral Reserve and therefore does not have demonstrated economic viability.

The QP has assessed reasonable prospects for eventual economic extraction (RPEEE) in accordance with CIM Definition Standards and CIM best-practice guidelines. This assessment is conceptual in nature and is based on the observed lateral continuity of nodule abundance and grade, together with assumed seabed collection and riser-lift mining concepts and established processing approaches for polymetallic nodules. Conceptual economic, environmental, and regulatory considerations appropriate to an early-stage project have been applied, and no significant factors have been identified that would preclude eventual economic extraction once the appropriate consents are in place. The Inferred Mineral Resource is subject to significant geological, technical, environmental, and regulatory uncertainty, and the QP cannot guarantee that further exploration or evaluation work will result in the delineation of Mineral Resources in higher confidence categories or the definition of Mineral Reserves.

1.5 Conclusions & Recommendations

In addition to the Inferred Mineral Resource in Table 1-1, in the QP's opinion, there is significant exploration potential to extend the mineral resources within MP 55549. Based on existing sampling data (which were not included in the resource because of lower density of sampling or lower SQR values), the exploration target would be in the order of 15,000,000 to 20,000,000 m³ at grades of 200 to 300 Ph kg/m³. The potential quantity and grade of this exploration target is conceptual in nature. As of the effective date of the Report, there has been insufficient exploration to define a Mineral Resource for this exploration target, and it is uncertain whether further exploration will result in the exploration target being delineated as a Mineral Resource.

The QP recommends that further seafloor sampling be undertaken to both increase the confidence of the classification of the MRE as well as to extend the boundaries of the resource, predominantly towards the west where currently low-quality *RV Valdivia* data indicate additional phosphorite potential. Increasing the confidence in the current MRE by additional sampling will give CRP the grade and geological confidence in the phosphorite deposit to undertake further development of mining plans and economic studies.

The QP suggests a two-staged work programme.

A first stage (Phase 1) would focus on further integrating all existing geological and environmental data to increase the confidence in both the mineral resource estimate and environmental models.

The current MRE is based on historical data and classified as an Inferred Mineral Resource because of its relatively low confidence. Contingent on the results of Phase 1, the QP recommends that for the second stage in the work programme (Phase 2), further seafloor sampling be undertaken to both increase the confidence in the established MRE and to extend the boundaries of the resource, predominantly towards the west where currently low-quality *RV Valdivia* data indicate an exploration target of 3 to 4 Mt phosphorite at potential grades of 200 to 300 Ph kg/m³. Increasing the confidence in the current MRE by additional properly located and documented sampling will give CRP and Boskalis the grade and geological confidence in the phosphorite deposit to allow them to further develop mining plans and economic studies.

The QP recommends that further exploration includes, but is not limited to:

- 400 × 400 m seafloor sampling using a large-sized pneumatic grab sampler;
- a thorough QA/QC programme for future sampling campaigns;
- logging of data indicating depth of mineralised sand layer;
- ROV transects of sample sites to confirm sample quality and depth of sample; and
- detailed bathymetric survey of mining blocks to delineate barren zones from outcrop, icebergs furrows and pits.

Approximate costs of this programme are illustrated in Table 1-2.

Table 1-2: Proposed work programme and cost.

Phase	Description	Cost (USD)
Phase 1: Data modelling	Further data integration and modelling	0.3M
Phase 2: Seafloor sampling	Sampling and resource update	4.7M

2. Introduction

2.1 Purpose of the Report

Chatham Rock Phosphate Limited (CRP) commissioned RSC Consulting Ltd (RSC) to prepare an independent technical report (the Report) in compliance with National Instrument 43-101: *Standards of Disclosure for Mineral Projects* (NI 43-101) and Form 43-101F1, in respect of the Chatham Rise Phosphorite Project (the Project) within New Zealand's Exclusive Economic Zone in the Pacific Ocean, ~450 km southeast of Wellington, New Zealand. The Project comprises one mining permit, MP 55549, which is wholly owned by CRP. The Report documents all data and data collection procedures for the Project, up to and including the effective date of 29 April 2026, and reports a Mineral Resource Estimate (MRE) for the Project.

2.2 Sources of Information

The information in this technical report is based on data supplied by CRP and Kenex Knowledge Systems (Kenex). Kenex was involved with data management at the start of the Project and supplied the QP with a Microsoft Access database of all sample data available for the Project. Scanned copies of the original raw data sheets for all 689 samples collected aboard the *RV Valdivia* and for all 500 samples collected aboard the *RV Sonne* were made available to the QP. In addition, the QP obtained a scanned copy of a printout of a historical database compiled at the time of sampling on the *RV Valdivia* from the archives of the German Federal Institute for Geosciences and Natural Resources (BGR). The QP, and staff under the QP's supervision, used the scans of original and historically recorded data to validate the sample data in the Kenex digital database.

The QP obtained information on how samples were collected and processed from cruise documentation as well as first-hand accounts by experts who were present aboard each cruise at the time of sampling. Information relating to property ownership, property titles, legal, environmental, or engineering matters was similarly sourced from third-party experts (see Section 3), as well as government publications.

A list of the sources of information, data, and reports reviewed as part of this technical report is presented in Section 28. The QP takes responsibility for the content of the Report and considers the data review to be accurate and complete in all material aspects.

2.3 Definitions

The Report contains a number of terms, denominations, and calculation methods that are specific to this style of mineralisation (Table 2-1). The deposit was assessed using measurements and estimations of the weight of phosphorite nodules relative to sample volumes collected from the seafloor. These measurements are presented as either *phosphorite grade*, expressed as weight per volume (kg/m^3), or *phosphorite nodule abundance*, expressed as weight per area (kg/m^2).

The determination of phosphorite grade and phosphorite nodule abundance was carried out using conventional methods (weighing and simple measurements of volume) and did not involve extensive laboratory analysis to determine P₂O₅ grade for each sample. Therefore, typical industry sample quality control measures, such as inserting certified reference materials (i.e. standards and blanks) were not used. This is because the intended product is saleable per kg of ‘phosphorite rock’, which, by definition (see Table 2-1) already has sufficient concentrations of phosphorus pentoxide.

Table 2-1: Phosphate mineral nomenclature used in the Report.

Definition	Grade	Description
P	%	The element phosphorus. It is a non-metallic chemical element and occurs in phosphate minerals in phosphatic rocks.
P₂O₅	%	Phosphorus pentoxide (chemical compound).
Phosphorite		Synonym: ‘rock phosphate’. Non-detrital sedimentary rocks or nodules that contain high amounts of phosphate-bearing minerals.
Rock phosphate		A general term that refers to a rock with high concentrations of phosphate minerals.
Phosphate minerals		The phosphate class of minerals is a large and diverse group; however, only a few species are relatively common.
Phosphorite grade	Ph kg/m ³	The weight of phosphorite nodules per cubic metre.
Phosphorite nodule abundance	Ph kg/m ²	The weight of phosphorite nodules per square metre of seafloor.
Penetration depth	m	The thickness of the mineralised sediment component in a sampling bucket.
True depth	m	The true depth of the mineralised sediment.

2.4 Qualified Person

This Report was completed by the following Qualified Person (QP):

René Sterk is a Fellow of the Australasian Institute of Mining and Metallurgy (AusIMM) and a Chartered Professional Geologist (CP Geo) with the AusIMM. René is the Qualified Person responsible for all sections of the Report. René holds an MSc in Structural Geology and Tectonics from the Vrije University Amsterdam (2002) and is a full-time employee and Managing Director of RSC, an independent international consulting group. His experience includes assessment and evaluation of seabed nodule deposits near New Zealand, Cook Islands, and in the Clarion-Clipperton Zone (CCZ). René has been the principal author of technical papers concerning seabed sampling techniques, and documentation of seabed resources prepared according to industry codes. He has presented at professional seabed mining industry conferences, facilitated resource estimation training workshops for the seabed mineral industry, and has also been involved with expert working groups addressing seabed mining policy. René is responsible for all sections of the Report.

2.5 Personal Inspection (Site Visit)

The QP has not visited the Project, as the mineralisation is 400 m below the sea surface and cannot be visited. For site-specific information, has relied on the experience of experts who were directly involved with sampling and estimating phosphorite nodule abundance (Dr Falconer, Dr Kudrass, Dr Nielsen; Table 2-2). The QP visited CRP’s subsampling site in Wellington on 16 January 2014.

The QP is of the opinion that the personal inspections by Dr Falconer and Dr Kudrass from 1978–1981 are current, as there has been no material change to the property. Nodule formation is measured on the scale of millions of years, and sedimentation rates on the scale of thousands of years. No significant surface disturbance to the area has occurred since the sampling by CRP.

Table 2-2: Site visits conducted by third-party experts and QP.

Name/organisation	Site visits	Expertise
Dr Robin Falconer, Director, CRP	<i>RV Sonne</i> leg 1 (March–April 1981) and leg 3 (May 1981)	<i>RV Sonne</i> sampling methodology, geophysical techniques, seismic facies
Dr Hermann Kudrass, former Director, German Federal Institute for Geosciences and Natural Resources (BGR)	<i>RV Valdivia</i> , October–November 1978 <i>RV Sonne</i> , leg 2 (April–May 1981)	<i>RV Valdivia</i> and <i>RV Sonne</i> sampling methodology; geology and geochemistry; historical resource estimations
Dr Simon Nielsen, former Senior Geologist, Kenex Knowledge Systems Ltd (Kenex)	<i>RV Dorado Discovery</i> cruise 2 (February 2012), cruise 3 (March 2012), cruise 4 (April 2012)	<i>RV Dorado Discovery</i> sediment sampling, remotely operated underwater vehicle (ROV), cone penetration testing (CPT)
René Sterk, Qualified Person Author	CRP subsampling site in Wellington, NZ (XX January 2014)	Qualified Person on seafloor nodules and phosphorites in Pacific Ocean and New Zealand

The QP confirms that no material work has been conducted on the Chatham Rise Project between the January 2014 visit to the subsampling site and the effective date of this Report. The QP has monitored public announcements made by CRP during this period and spoken with CRP management and its technical team, and has confirmed that no new exploration activities have occurred or been reported since the January 2014 site visit. Based on the data assessment and verification methods used, the QP is of the opinion that another site visit is not required at this time for the Project.

3. Reliance on Other Experts

The QP has not independently verified the legal status of CRP's mineral permits, and has not investigated the legality of any of the underlying agreements that exist concerning the Project discussed in Section 4 of this Report.

The QP has reviewed CRP's permit status information on the Ministry of Business, Innovation & Employment (MBIE) — New Zealand Petroleum and Minerals (NZP&M) website. The QP relied on the NZP&M website and the permit certificate issued under the Crown Minerals Act (1991) (certificate dated 6 December 2013), which states CRP's legal status and title of prospecting, exploration, and mining. However, the QP is not qualified to give a legal opinion with respect to the property titles and discussed in Section 4 of this Report.



4. Property Description & Location

4.1 Location

The Chatham Rise Project is located in the Pacific Ocean ~450 km southeast of Wellington, New Zealand, within New Zealand's EEZ, on New Zealand's Continental Shelf (Figure 4-1). The centre of the Project area is at latitude 43° 30' S and longitude 179° 30' E (WGS84 datum and coordinate system) at a water depth of 350–450 m and is fully within New Zealand's jurisdiction according to international law.

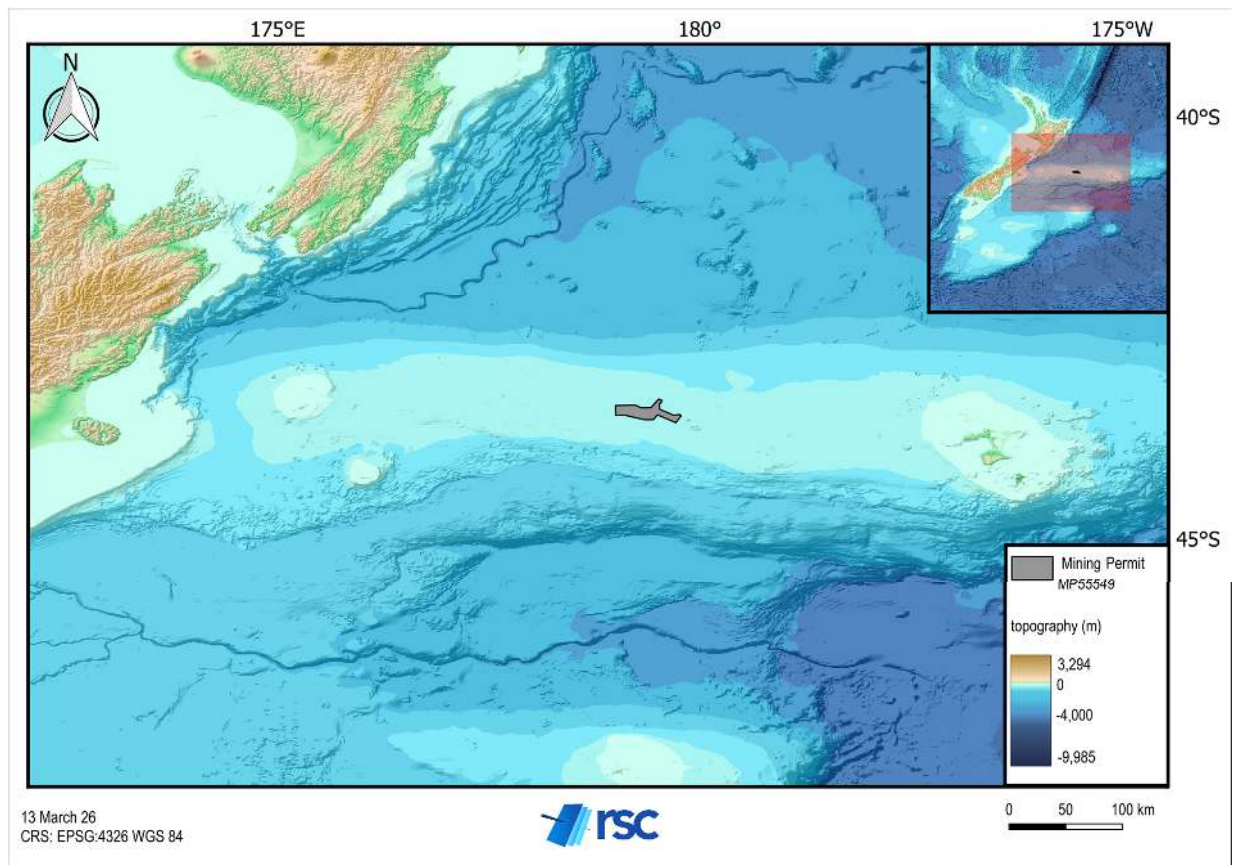


Figure 4-1: Location of the Project.

4.2 Mineral Tenure

4.2.1 Mineral Rights

Within New Zealand, the allocation of rights to prospect, explore, and mine for minerals owned by the Crown is carried out by the granting of prospecting, exploration, and mining permits under the Crown Minerals Act (CMA) (1991). The Minister of Resources is responsible for the CMA, and the administration of the CMA has been delegated to the Ministry of Business, Innovation & Employment (MBIE), through the brand name NZP&M — the government regulator responsible for managing New Zealand's Crown mineral estate.

Under the CMA, all petroleum, gold (Au), silver (Ag), and uranium (U) in its natural state is deemed to be owned by the Crown, and pounamu (greenstone) is owned by Te Rūnanga o Ngāi Tahu. The granting of a prospecting, exploration, or mining permit provides the permit holder the right to prospect, explore, or mine the minerals specified in the permit. Applications for U and thorium (Th) will ordinarily be declined.

Permits under the CMA are classified as Tier 1, 2, or 3 depending on the minerals they relate to, the activities to be undertaken, expected work programme expenditure, estimated production or royalty, and where the activities take place. All prospecting permits are classified as Tier 2. Exploration permits for Au, Ag, metallic minerals, and platinum group metals (PGMs) are classified as Tier 1 unless the expected total work programme expenditure for the final five years of its life is <NZD 1,250,000. Mining permits for Au, Ag, and PGMs are classified as Tier 1 if, in any one permit year in the next five years of its life, the annual royalty will be equal to or more than NZD 50,000. Mining permits for any other metallic mineral are classified as Tier 1 if, in any one permit year in the next five years of its life, the annual production will be equal to or more than 500 kt of metallic minerals ore. All exploration or mining permits for underground operations or operations that are (wholly or partially) 50 metres or more beyond the sea-ward side of the mean high-water mark are classified as Tier 1.

4.2.1.1 Prospecting Permits

Prospecting is any activity undertaken for the purpose of identifying land likely to contain mineral deposits or occurrences.

A prospecting permit gives the permit holder the exclusive right (although non-exclusive permits are also available) to prospect for the minerals referred to in the permit, in the land covered by the permit, and in accordance with the permit's conditions.

The permit conditions are subject to the following.

1. The rights under a prospecting permit apply to the relevant minerals whether they are Crown or privately owned. However, any extraction of privately owned minerals, beyond that incidental to prospecting, requires negotiation and agreement with the mineral owners.
2. The holder of a prospecting permit has a *prima facie* right to be granted a subsequent exploration permit in respect of the land and Crown-owned minerals to which the prospecting permit relates, if the prospecting is successful.

A prospecting permit is granted for a period of two years, with the possibility of extension for a further two years. There are no rights of renewal beyond four years. When a prospecting permit for minerals is renewed, the Minister typically requires relinquishment of half of the permit area.

Ordinarily, the maximum size of an offshore prospecting permit granted by NZP&M is 5,000 km², with the expectation that the size of any subsequent exploration permit will be smaller than the original prospecting permit.

A minimum annual fee for prospecting permits is payable to the Crown. For offshore prospecting (i.e. >12 nm), the fee is NZD 3.58 per km² or part thereof, or NZD 1,610, whichever is greater

CRP does not currently hold any prospecting permits.

4.2.1.2 Exploration Permits

Exploration is any activity undertaken for the purpose of identifying mineral deposits or occurrences and evaluating the feasibility of mining.

An exploration permit gives the permit holder the same rights as a prospecting permit, plus the exclusive right to explore for the Crown-owned minerals referred to in the permit, in the land covered by the permit and in accordance with the permit's conditions. An exploration permit cannot authorise exploration for privately owned minerals (noting, however, that all petroleum, Au, Ag and U, existing in its natural state is deemed to be owned by the Crown under the CMA).

The Crown typically owns all minerals in the territorial sea (up to 12 nm) and has vested rights in minerals in the exclusive economic zone (EEZ; i.e. from 12–200 nm off the coast of New Zealand) and the continental shelf beyond (to a maximum of 350 nm offshore).

Subject to the permit conditions, the holder of an exploration permit has a *prima facie* right to be granted a subsequent mining permit, in respect of the land and Crown-owned minerals to which the exploration permit relates, if the exploration is successful.

An exploration permit (for minerals other than petroleum) is typically granted for a period of five years, with the possibility of an extension for an additional five years. There are no rights of renewal beyond ten years, except for appraisal purposes. Appraisal extensions may extend the duration of an exploration permit by up to eight years. When an exploration permit for minerals is renewed, the Minister typically requires relinquishment of half of the permit area.

NZP&M does not specify a maximum size for an exploration permit but does dictate that an exploration permit must not be smaller than 150 hectares.

There is a minimum annual fee for exploration permits that are payable to the Crown. For offshore exploration, the fee is NZD 10.73 per km², or part thereof, or NZD 1,610, whichever is greater.

CRP does not currently hold any exploration permits.

4.2.1.3 Mining Permits

Mining is taking, winning, or extracting, by any means, a mineral existing in its natural state.

A mining permit gives the permit holder the same rights as an exploration permit, plus the exclusive right to mine for the specified Crown-owned minerals referred to in the permit, in the area covered by the permit, and in accordance with the permit's conditions. A mining permit cannot authorise exploration or mining for privately owned minerals (noting, however, that all petroleum, Au, Ag and U, existing in its natural state is deemed to be owned by the Crown under the CMA (1991)).

The Crown typically owns all minerals in the territorial sea (up to 12 nm) and has vested rights in minerals in the exclusive economic zone (EEZ; i.e. from 12–200 nm off the coast of New Zealand) and the continental shelf beyond (to a maximum of 350 nm offshore).

A mining permit remains in force for a maximum period of 40 years. The duration of a mining permit may be extended if the discovery to which the permit relates cannot be economically depleted before the date of expiration.

There is a minimum annual fee for exploration permits that is payable to the Crown. For offshore exploration, the fee is NZD 10.73 per km², or part thereof, or NZD 1,610, whichever is greater.

CRP currently holds one mining permit, MP 55549.

4.2.1.4 Revocation of Permits

The Minister may revoke a permit if:

1. the permit holder contravenes a condition of the permit, the CMA, or regulations made under the CMA;
2. the permit is a Tier 1 permit, the permit holder is the permit operator, and the permit holder undergoes a change of control without the Minister's consent; or
3. the permit holder undergoes a change of control without notifying the Minister, or the Minister is not satisfied the permit holder, following the change of control, has the financial capability to meet its obligations under the permit.

The conditions for CRP's mining permit are in Schedules 1–3 of the permit certificate.

4.2.2 Permit Status

CRP holds 100% of MP 55549 (820 km²) (Table 4-1). Boskalis previously provided significant technical services to CRP in respect of the Project and held a 7.6% shareholding of CRP as of 1 May 2014. Boskalis no longer holds any shares of CRP (as at the effective date of the Report).

Table 4-1: CRP licence holdings.

Permit No.	Permit Type	Area (km ²)	Ownership	Grant Date	Expiry Date
MP 55549	Mining Permit	820	CRP 100%	6 December 2013	5 December 2033

Mining Permit 55549

The Minister of Economic Development granted MP 55549 to CRP for the extraction of rock phosphate on the Chatham Rise on 6 December 2013 (Figure 4-2). The permit was granted for 20 years and is due to expire on 5 December 2033. As part of the permit conditions, a Marine Consent must be obtained from the EPA before mining can commence. Figure 4-1 and Figure 4-2 illustrate the extent of MP 55549.

Prospecting Licence 50270

MPL 50270 was originally granted to Widespread Energy Ltd (90%) and Widespread Portfolios Ltd (10%) on 25 February 2010, covering an area of 4,726 km². Widespread Portfolios Ltd sold its 10% holding in the joint venture to Widespread Energy Ltd (31 March 2011), after which Widespread Energy Ltd changed its name to Chatham Rock Phosphate Ltd (April 2011).

MPL 50270 was granted by the Minister of Economic Development under the Continental Shelf Act 1964 (the CSA). At the time the licence was granted, the CSA provided the legislative framework for the allocation of mineral rights for prospecting, exploration, and mining activities on New Zealand’s continental shelf, including areas beyond the territorial sea (12 nm).

MPL 50270 was granted subject to licence conditions, including environmental conditions that required the licence holder to undertake environmental baseline studies and to monitor and report on the environmental effects of exploration activities. These conditions also required compliance with internationally recognised environmental management guidelines relevant to marine mineral exploration.

The subsequent Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (the EEZ Act) established a comprehensive environmental management regime for activities undertaken within New Zealand’s EEZ and continental shelf beyond the territorial sea, addressing a previous regulatory gap. The enactment of the Crown Minerals Amendment Act 2013 transferred responsibility for the allocation and management of mineral resources in the EEZ and on the continental shelf from the CSA to the CMA. As a result, prospecting, exploration, and mining for minerals in offshore areas beyond the territorial sea (12 nm) are now regulated under the same minerals permitting framework as onshore activities, while environmental effects are regulated separately under the EEZ Act.

The original term of the MPL 50270 licence expired on 25 February 2014, and an application to extend the term for a further four years was submitted to NZP&M on 20 December 2013. The application was approved in August 2016 through to February 2020 over a reduced area of 2,887 km². MPL 50270 was surrendered on 29 August 2019.

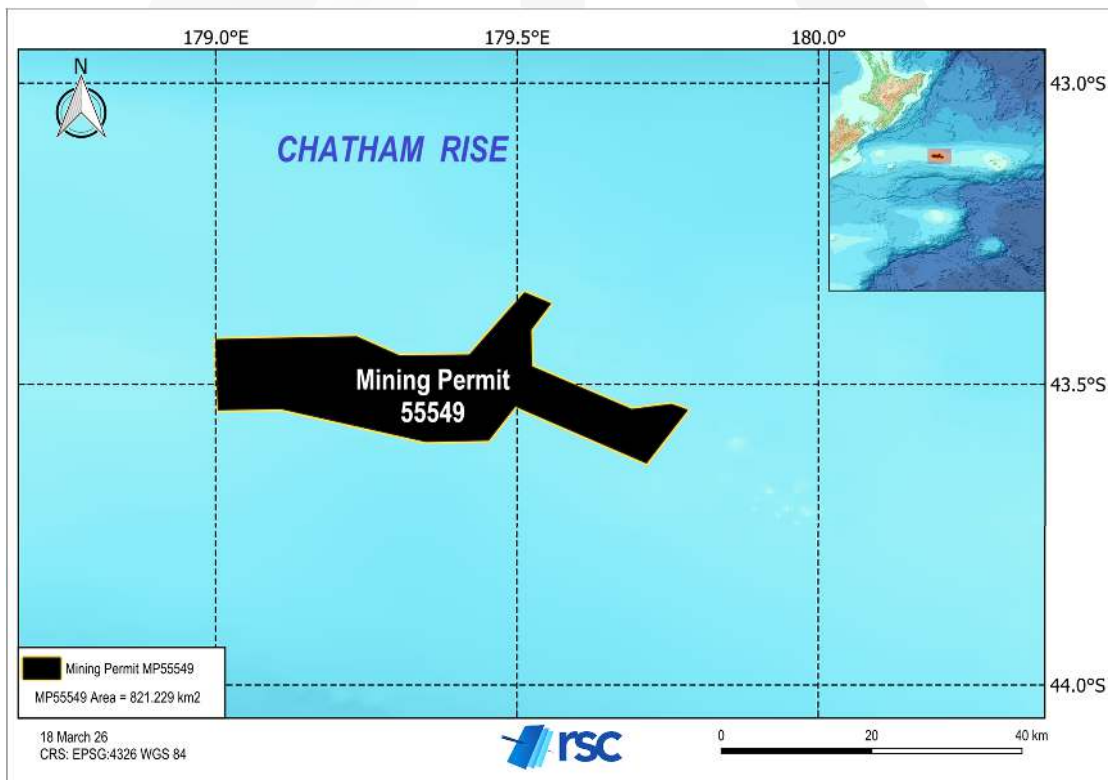


Figure 4-2: Extent of MP 55549, Chatham Rise.

4.2.2.1 Work Programmes

An applicant for a permit under the CMA must propose a minimum work programme for the proposed permit. The Minister will not grant the permit unless the Minister is satisfied the work programme is consistent with the CMA, the purpose of the permit, and good industry practice, and that the applicant is likely to comply with and give proper effect to the work programme. In addition, the work programme for a subsequent permit or permit extension of duration must be approved by the Minister. A permit holder may apply to the Minister to change the work programme for the permit.

Mining Permit 55549

The key requirements of the minimum work programme that was approved by the Minister outlined in Schedule 3 of MP 55549 requires CRP to (among other things):

- complete an updated resource optimisation and schedule study for the permit area;
- commence mining at a minimum rate of 800kt of phosphorite per annum (landed to port); and
- spend a minimum of NZD 2.0 million per annum for the first five years of production in carrying out these and other activities detailed in the work programme.

During 2018, CRP identified environmental and engineering parameters influential to the optimisation of the resource extraction (MR5599). CRP's consolidation of all benthic ecology data from previous environmental surveying was complemented by new data from NIWA (National Institute of Water and Atmospheric Research (New Zealand)). CRP initiated the running of alternative mine planning/scheduling scenarios to include some environmental parameters (i.e. removal of some areas of the resource due to presence of corals) to understand the impact this has on mine planning, scheduling, and economics. The scenarios involved removing parts of the resource from the schedule made up of 500-m or 1,000-m buffers around areas noted as containing potentially significant concentrations of corals. Modelling of the scenarios indicated only minimal impact on the project economics.

In March 2026, CRP issued a letter of commitment to NZP&M with respect to the 'commit or surrender' requirements of Condition 6 of the work programme, which states the following:

- Within 145 months of the commencement date of the permit, the permit holder shall (to the satisfaction of the chief executive) either:
 - make a commitment by notice in writing to the chief executive to complete paragraphs 7 and 8 of the work programme and continue production at a minimum rate of 800 kt of phosphate per annum; or
 - surrender the permit.

Following receipt of the letter, NZP&M considers CRP to be "late, but compliant" with that obligation, while noting that ongoing production at 800 kt per year could not be met. As at the effective date of this Report, NZP&M does not intend to take any enforcement action or revocation with respect to the permit pending the outcome of subsequent change of control and/or change of conditions applications, provided the applications are submitted in a timely manner, comply with the requirements of the CMA (1991) and relevant regulations, and all other applicable obligations under the CMA (1991) are complied with during that time, including the requirement to pay annual fees and submit reports in accordance with the

regulations and permit conditions. NZP&M further notes CRP has committed to lodge full marine consent applications by 30 November 2027, whether that is under the Fast Track Approvals Act (2024) or the Exclusive Economic Zone and Continental Shelf Act (2012).

4.3 Royalties & Encumbrances

4.3.1 Crown Royalties

One of the purposes of the CMA is to provide a fair financial return to the Crown for its minerals, which is achieved through a system of mandatory Crown royalties.

The Crown Minerals (Royalties for Minerals Other than Petroleum) Regulations 2013 (Royalty Regulations) set out rates and provisions for the payment of Crown royalties on non-petroleum mineral production. The Royalty Regulations provide for the payment of royalties on exploration and mining permits, to the extent minerals are produced from the permits.

Subject to certain thresholds (notably, a net sales revenue threshold of NZD 200,000 per annum), the royalty regime under the Royalty Regulations for Tier 1 permits, for metallic minerals, is:

- for Au and net sales revenue from Au, of not more than NZD 2 million per annum, an *ad valorem* royalty of 2% of net sales revenue; otherwise
- the higher of an *ad valorem* royalty of 2% of net sales revenue or an accounting profits royalty of 10% of accounting profits.

For Tier 2 permits, the royalty regime under the Royalty Regulations for metallic minerals is an *ad valorem* royalty of 1% of the net sales revenue(s) of the minerals obtained under the permit.

For Tier 3 permits, the royalty regime under the Royalty Regulations for Au is an *ad valorem* royalty of 1% of the net sales revenue(s) of the minerals obtained under the permit.

CRP's mining permit (MP 55549) is a more than 50 m offshore, so is therefore Tier 1.

4.4 Environmental Liabilities & Permits

As the Project is located offshore within New Zealand's EEZ, it is subject to different conditions from those applying to onshore mineral exploration and production activities. In addition to the standard permit requirements under the CMA (1991) and the EEZ Act (2012), along with regulations administered by NZP&M, the Project must comply with offshore-specific requirements set by the Environmental Protection Authority. Development of the Project is contingent upon obtaining appropriate minerals permits and marine consents addressing environmental effects on the seabed and water column.

The Project may be eligible for consideration under New Zealand's Fast-Track Approvals Act (2024), which provides an alternative consenting pathway for certain projects and establishes a permanent, fast-track approvals regime for projects of national and regional significance. It is administered by the Ministry for the Environment, with other agencies responsible for specific Acts related to project approvals, including DOC, MBIE, the Ministry for Primary Industries, Heritage New

Zealand Pouhere Taonga, and the Environmental Protection Authority. The system is intended to provide a 'one-stop shop' for resource consents, notices of requirement, certificates of compliance under the RMA, and approvals required under several other acts, including the CMA, the Conservation Act 1987, and the Wildlife Act 1953. The Fast-track Approvals Act 2024 received royal assent on 23 December 2024. Eligibility, processes, and outcomes under the new legislation are discretionary; therefore, they cannot be assured.

As at the effective date of this Report, no production consents or approvals had been granted to CRP under the Fast Track Approvals Act, and any future mining activities would remain subject to detailed environmental assessment and ongoing compliance obligations under the applicable EEZ regulations. However, CRP has committed to lodging full marine consent applications by 30 November 2027, either under the Fast Track Approvals Act or the EEZ Act.

CRP submitted a Marine Consent application and Environmental Impact Assessment (EIA) to the EPA on 14 May 2014 and subsequently submitted an updated EIA on 12 November 2014. CRP consulted with 'existing interests' (as required by the EEZ Act), indigenous peoples, the Chatham Islands community and other stakeholders. Parties with existing interests in the area mainly consist of the commercial fishing industry, including the indigenous fishing industry. The nature of this consultation and the issues raised during consultation were included in the EIA, which consisted of an analysis of CRP's proposed activities, the potential effects of those activities, and how any adverse impacts arising from the Project could be managed (see Section 4.2.2.1).

On 10 February 2015, a Decision-making Committee (DMC) appointed by the EPA refused CRP's Marine Consent application, based on concerns over the destructive impact of the drag-head on the seabed and on benthic fauna and the potential adverse effects of the return of waste material on the benthic habitat in and around the Project area. The DMC noted that the impacts could not be avoided, remedied, or mitigated, and that mining would be occurring mainly within the Mid Chatham Rise Benthic Protection Area. The DMC further noted that the effects would include the destruction of communities dominated by protected stony corals that are potentially unique to the Chatham Rise and are thus considered rare and vulnerable ecosystems, and raised concerns that the habitat could not be restored to its present form and would instead be transformed wholly into a soft-sediment habitat. While the decision was a setback, CRP may pursue a re-submission of its Marine Consent application. CRP intends to continue to work with the EPA to seek clarity on the interpretation of the EEZ legislation and the EPA's policies and procedures for managing the consent process.

The decision to decline the Marine Consent had a direct influence on progressing work on MPL 50270 with respect to raising the necessary capital to undertake the prospecting work programme. Accordingly, MPL 50270 was subsequently surrendered in 2019.

4.5 Other Significant Factors & Risks

Mining in New Zealand is a sensitive and political subject and, as in many other countries, there are active anti-mining groups.

Exploration and mining projects within New Zealand can be the subject of negative campaigns by emboldened local and online anti-mining groups. In 2025, Trans-Tasman Resources (TTR) sought approval under the Fast-Track Approvals Act

to mine iron sands from the seabed of the South Taranaki Bight, off the west coast of New Zealand's North Island, proposing to extract up to 50 Mt of seabed material annually for a period of 20–30 years¹. TTR promoted the project as a source of critical minerals, including vanadium, and reported plans to deliver substantial economic benefits on regional and national scales. However, various anti-mining groups, iwi, fishing interests, and environmental organisations viewed TTR's decision to apply through the Fast-Track Approvals process as an attempt to bypass the intense scrutiny and sustained opposition that the project had faced in previous EPA and court proceedings over more than a decade. Concerns raised by the various opposing bodies were echoed by the Expert Panel's draft decision on TTR's application, released on 4 February 2026, which proposed that the application should be declined. Shortly after the draft decision was released, TTR withdrew its application before a final decision could be made. Anti-mining advocates interpreted the withdrawal as confirmation that the proposal could not meet the necessary environmental thresholds, reinforcing calls for a broader policy shift away from seabed mining and towards stronger marine protection across the EEZ².

The current New Zealand Government, which is a National-led coalition with New Zealand First and Act parties, strongly supports mining and has discussed plans to double mining earnings over the next decade. This has created a very positive authorising environment for mineral exploration, and the potential to fast-track permitting processes in the event of a discovery through the Fast-track Approvals Act 2024.

¹ <https://www.nz.co.nz/news/national/586083/fast-track-panel-declines-taranaki-seabed-mining-over-risk-to-marine-life>

² <https://newsroom.co.nz/2026/02/19/besieged-mining-firm-withdraws-fast-track-bid-to-plough-taranaki-seabed/>

5. Accessibility, Climate, Local Resources, Infrastructure & Physiography

5.1 Accessibility

The deposit lies on the crest of the Chatham Rise ~450 km southeast of Wellington, New Zealand (Figure 4-1). Water depths in the area of main interest vary from 350–450 m.

Exploration operations are conducted by ocean-going vessel and there are no restrictions of access to the site. The site is outside major shipping lanes; however, public notices to mariners would have to be filed for any deployment of equipment, moorings, or operations that could affect shipping.

5.2 Climate

The site is located at 43–44° south and subject to the climate and weather patterns of the southern Pacific Ocean, but these are not anticipated to be extreme. Sea conditions were considered in the mining design studies that have been undertaken to date.

The Chatham Rise lies at the boundary between warm, saline subtropical waters to the north and cooler, less saline sub-Antarctic water to the south. The boundary is known as the Subtropical Convergence or Subtropical Front. Although the surface sea conditions can be harsh, these do not influence water movement at the water depths in the proposed Mining Permit area. Measurements of ocean currents in the Mining Permit area indicate that seabed currents are highly variable.

Sea temperatures typically range from 8–15°C. Therefore, vessel icing or sea ice is not expected to be a significant factor in the mining operation. Icebergs have been observed historically in the Project area; however, they are rare, as they originate in Antarctica over 2,000 km to the south. It is not anticipated that icebergs would represent a threat to mining operations.

5.3 Local Resources & Infrastructure

Boskalis outlined the port requirements for the type of vessel proposed for the mining and transportation of phosphorite at the Project. A key requirement is the ability to handle dry bulk goods and having a draft capability of 11 m (including access channels). Major ports for logistical support and potential future offloading sites are located throughout the country (Figure 5-1, Table 5-1). Many of these ports already handle bulk fertilisers. Ship-to-ship transfers could also be conducted in the sheltered areas of the Marlborough Sounds, near Picton.

All exploration and mining operations will have to be undertaken from vessels. The mining vessel will supply its own power requirements. Seawater will be used for mining and processing (washing and sieving). Fine material (tailings) would be returned to the seafloor via a return pipe, and the retained phosphorite would be stored within the ship's holds. It is anticipated that mining will be undertaken from a specialised deep-water dredging/mining vessel. Material transport to shore will be via the mining vessel or by transport vessels loaded at the mining site.

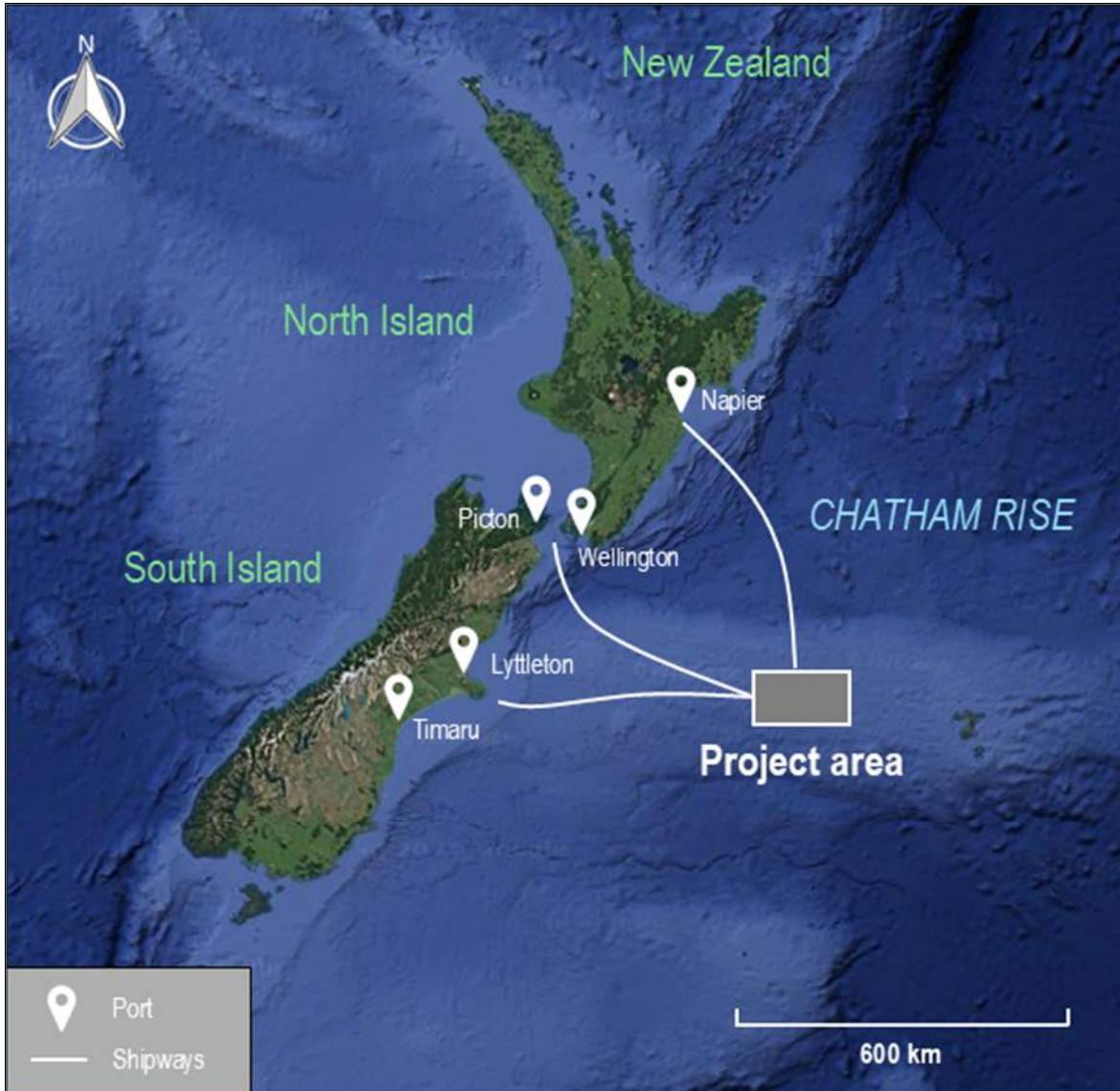


Figure 5-1: Project location and New Zealand ports that could potentially be used.

Table 5-1: Potential ports for offloading bulk phosphorite.

Port	Distance (km)	Maximum draught (m)	Dredging required?	Dry bulk handling facilities?
Napier	556	12.4	Yes	Yes
Wellington	592	11.4	Yes	Yes
Picton	682	13.5	No	Yes
Lyttelton	660	13.3	Yes	Yes
Timaru	780	10.6	Yes	Yes

5.4 Bathymetry

The Project area is elongated east to west along the crest of the Chatham Rise (Figure 5-2).

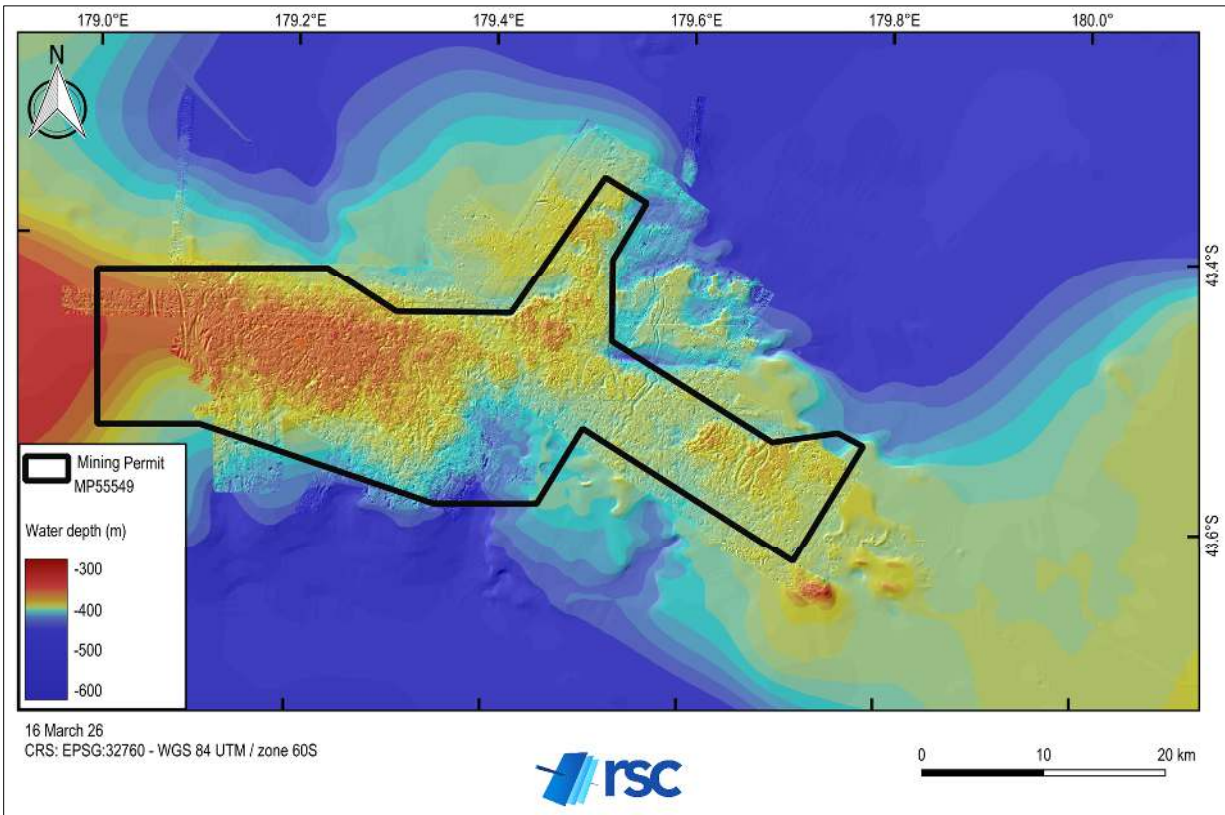


Figure 5-2: Bathymetry of the Project area.

Within the Project area, water depths increase from 300 m in the centre to over 600 m in the south and north. The area of primary interest is on the crest of the rise in water depths of 350–450 m, with a saddle depth of 390 m. Sub-areas of pronounced micro relief – up to 5 m in height and roughly 50 m in horizontal extent – are superimposed on broader topographic variations of 20 m relief and 0.5–1 km extent. Maximum seabed slopes seldom exceed 10°, but some steeper scarps may be present.

The surface sediments of the Chatham Rise predominantly comprise an unconsolidated mixture of greenish-grey muddy sands and sandy muds containing spatially variable amounts of phosphorite grains and nodules. The nodules formed at ~5 Ma, and the surrounding sediment is derived from 20–10 Ma limestones and chinks and overlies Oligocene chalk. In shallower parts of the Chatham Rise, away from the proposed mining area, outcrops of hard igneous or metamorphic basement rock occur.

6. History

6.1 Tenure & Operating History

Various programmes have been undertaken by private and government-funded organisations in the Project area since the 1950s. Initial reconnaissance surveys were conducted by the New Zealand Geological Survey in 1952 and Global Marine Inc. (Global Marine) in 1967–68. The reconnaissance surveys carried out dredge sampling over much of the Chatham Rise, noting the presence/absence of phosphorite nodules, in an attempt to prioritise areas for future expeditions.

Global Marine held the first mineral prospecting licence (MPL) over an area of 100,000 km² across the Chatham Rise. From 1971, JBL Exploration NZ Ltd (JBL) held a prospecting licence covering a portion of the MPL previously held by Global Marine.

From 1975–1978, the New Zealand Oceanographic Institute (NZOI) conducted a localised survey to determine the distribution and thickness of phosphorite-bearing sediments over part of the area now covered by MP 55549. After this campaign, a collaboration between the West German Government and the New Zealand Department of Scientific and Industrial Research (DSIR) launched two extensive sampling surveys, one in 1978 using the *RV Valdivia*, and the second in 1981 using the *RV Sonne*. Together, the two campaigns collected over 1,100 sediment samples, the vast majority from within the area previously held by CRP under MPL 50270.

The New Zealand company, Fletcher Challenge Ltd, was involved in the 1981 work and was granted a prospecting licence for further investigation of the phosphorite deposits, but no further data collection surveys were undertaken, and the licence was allowed to lapse in 1984.

No further mineral permits were issued over the Chatham Rise until MPL 50270 was granted to CRP in 2010.

6.2 Exploration History

6.2.1 RRS Discovery II (1952)

Officers of the New Zealand Geological Survey first discovered marine phosphorite deposits in sediments on the Chatham Rise in 1952 when mineralised material was dredged by the *RRS Discovery II* ~130 km west of the Chatham Islands. No data from this cruise were available for review as at the effective date of the Report.

6.2.2 MV Moray Rose & MV Taranui (1967–1968)

Global Marine conducted an extensive exploration programme including reconnaissance sampling over much of the Chatham Rise in February–March 1967, followed by a detailed sampling survey of the area between 178°48' E and 177°50' W in February–March 1968 (Figure 6-1). In total, 337 samples were collected, with phosphorite nodules recovered in 137 samples, from an area of ~18,500 km² (Ross, 1967; Global Marine Inc., 1968). The primary purpose of the investigation was to identify the extent of phosphorite on the Chatham Rise and to determine its origin (Pasho, 1976).

The *MV Moray Rose* conducted the first phase of sampling, while the larger *MV Taranui* was used during the second stage. Both ships used celestial navigation to position themselves on pre-determined sample locations (Global Marine Inc., 1968).

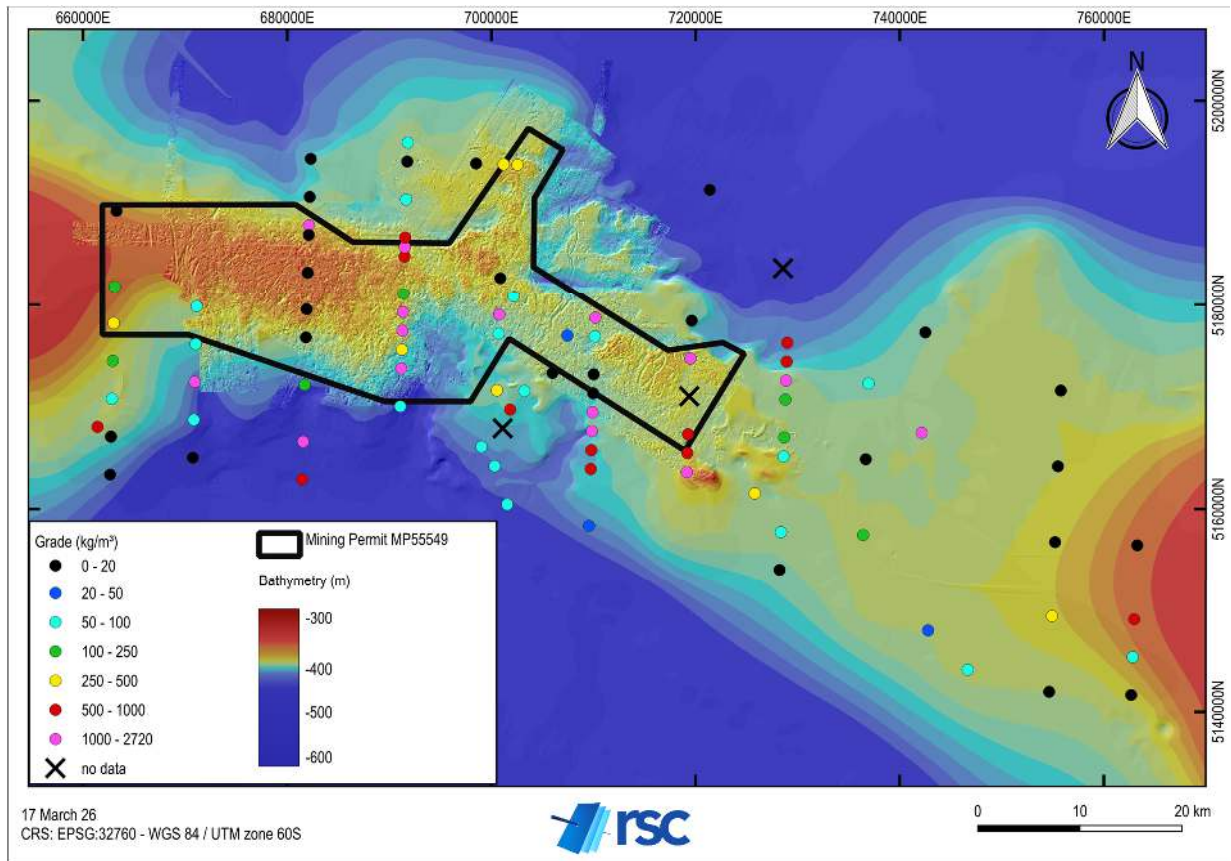


Figure 6-1: Global Marine's sample locations within the previous MPL 50270 area and updated phosphorite grade from Global Marine's unvalidated phosphorite Ph kg/m³ data.

6.2.2.1 Sampling Method

Sampling was conducted using a custom-built pipe dredge with a diameter of 45 cm. The length of the pipe was not recorded; but, based on faded photographs of sampling aboard the *MV Taranui* (Global Marine Inc., 1968), the pipe is likely to have been ~1.5 m long. Upon reaching a sampling station, the ship's engines were stopped and the pipe dredge lowered to the bottom at a moderate rate to prevent fouling of the 1.27-cm (½-inch) gauge wire line. The pipe dredge was then towed behind the slow-moving *MV Moray Rose* or dragged behind the drifting *MV Taranui*; this change in procedure was due to the increased level of work involved in stopping and starting the larger vessel (*MV Taranui*). In both cases, the pipe dredge was dragged along the bottom until it was full (as indicated by increased strain on the line), at which point it was retrieved (Global Marine Inc., 1968). Once on board, the pipe was upended and its contents dumped on the deck of the ship. A subsample was taken (method not disclosed), and the remainder of the material was washed overboard using a fire hose (Global Marine Inc., 1968).

Sample collection occurred at regular 4-mile (6.44-km) intervals along north-trending lines spaced 5 miles (8.05 km) apart. Celestial navigation was used to position each ship at the predetermined sample locations (Global Marine Inc., 1968). The accuracy of this method of navigation depends entirely on the skill of the navigator and the quality of the instruments used and, at best, it has an accuracy of 3–4 nm (5.5–7.4 km) (Wood et al., 2003). However, despite the limited accuracy of the results, the sample collection process was an important first step in identifying phosphorite potential on the Chatham Rise, and the results were critical in guiding later surveys.

6.2.2.2 Sample Preparation & Analysis

Raw data for the Global Marine samples are presented in Ross (1967). All 331 samples were briefly geologically described at the time of collection. A total of 41 samples were sieved into three size fractions (<0.152 mm, 0.152–2.38 mm, and >2.38 mm) and the main constituents of each fraction were noted. A further six samples were sieved into 12 size fractions (<0.152 mm, 0.152–0.211 mm, 0.211–0.297 mm, 0.297–0.599 mm, 0.599–1.20 mm, 1.20–2.38 mm, 2.38–4.763 mm, 4.763–9.525 mm, 9.525–19.05 mm, 19.05–38.1 mm, 38.1–76.2 mm, and >76.2 mm). All size fractions from the samples were analysed for P₂O₅, CaCO₃, and K concentrations. Analysis methods were not recorded for the samples, but analyses were conducted at Smith-Emery Laboratory, Los Angeles, and an unknown laboratory in New Zealand. In addition, 35 bulk-sediment samples were analysed for P₂O₅ using x-ray fluorescence (XRF) at Raymond G Osborne Laboratories, Los Angeles. A discrepancy between laboratory analyses is reported by Ross (1967); however, it is not clear whether this was resolved, as the author only indicates that the discrepancy meant that some analyses may have been higher than reported.

In addition to the Global Marine analyses, phosphorite nodules from the Global Marine cruises were investigated by Pasho (1976). Pasho analysed nodules from 51 samples for their P₂O₅ grades using splits of crushed whole-nodule cross-sections or from a specific region of a nodule interior. The analytical samples were ground to <0.125 mm and oven dried for 24 hours at 110°C, then fused with La₂O₃ and Li₂B₄O₇ and pressed into sample wafers. Analyses were performed on a Norelco XRF unit (Pasho, 1976).

Pasho (1976) also used modal analysis of 43 thin sections from 40 nodules to determine the composition and abundance of the nodule constituents. An unspecified number of polished sections were etched with formic acid to distinguish phosphatic material from carbonate. Finally, the mineralogy of the contained clastics in the nodules was determined by performing a grain count on the residue of an unspecified number of nodules digested in hydrochloric acid (HCl). Grain size distributions were determined by point counting grains within sieve intervals (sieve sizes not reported) (Pasho, 1976).

6.2.2.3 Density & Moisture Content

No density or moisture content data were reported by Global Marine. Pasho (1976) reported that phosphorite nodule densities varied from 2.4–3.0 g/cm³, with a negative correlation between nodule size and density.

6.2.2.4 Quality Assurance

At the effective date of the Report, no information was available on any quality assurance procedures being implemented during collection of the Global Marine samples, and no information was available with respect to the technique used to

subsample the pipe dredge samples or how representative the sampling was. The deck of the ship used for processing sample material is described as having been washed down with a fire hose between sampling batches (Global Marine Inc., 1968), which ought to have minimised cross-contamination between samples. No field duplicates were available; sample 46A is reportedly the same as sample 46 according to the sample description, but the latitudes recorded for each sample indicate the samples were not collected at the same location (Ross, 1967). Pasho (1976) describes how 'duplicates of all samples' were provided by Global Marine for assessment purposes, but there is no record of when, where, or how these were collected or separated out from the original sample material. Pasho (1976) does not indicate whether certified reference materials were used for laboratory analyses.

6.2.2.5 Logging

A geological description of each sample was recorded at the time of collection. Though not reported in detail, these descriptions included observations of the presence/absence of phosphorite nodules, lithological affinity (i.e. indurated limestone), texture (borings, encrustations), grain shape, size, and colour. Brief descriptions and grain size ranges are reported in the literature (Global Marine Inc., 1968).

6.2.2.6 Estimation of Phosphorite Grade in Samples

The QP estimated the phosphorite grade of the samples by multiplying the reported volume percentages of phosphorite for each sample by an assumed average wet density of phosphorite nodules of 2.72 g/cm³ (based on the most recent density data collected by CRP, Section 11.2). This yielded phosphorite grades up to 2,720 Ph kg/m³ (100% phosphorite) with an average grade of 210.0 Ph kg/m³.

The average P₂O₅ grade of the 35 bulk sediment samples submitted to Raymond G Osborne Laboratories, Los Angeles, was 4.7% (Ross, 1967). Subsequent analysis of phosphorite nodules isolated from 51 Global Marine sediment samples yielded an average P₂O₅ grade of 20.5% (Pasho, 1976).

Due to the nature of the pipe dredge sampling apparatus and technique, representative phosphorite grade estimations cannot be made from the Global Marine sampling data. While Pasho (1976) states that the pipe dredge was of sufficient diameter to prevent grain size bias during sample collection, accurate constraints on sampling area cannot be applied, as the pipe was retrieved only when full, regardless of the time or distance required for this to occur, and the time/distance data were not recorded. Global Marine and subsequent operators inferred that the pipe dredge was only capable of sampling the top 'few inches' of sediment (Ross, 1967), and the QP considers this insufficient penetration to be representative of a resource that is vertically variable and has an average thickness of ~22 cm. Global Marine analysed numerous samples for phosphorite grade and used the data to prioritise areas for subsequent exploration. The QP does not consider these data to be of sufficient quality to be included in phosphorite resource grade calculations.

6.2.3 JBL Exploration NZ Ltd (1971–1975)

From 1971, JBL Exploration NZ Ltd (JBL) held a prospecting licence covering a portion of the MPL previously held by Global Marine and proposed to undertake a detailed exploration programme. Over the next few years, JBL produced reports

outlining resource estimates, economic potential, and mining feasibility studies but did not complete any further sampling surveys over its licence area. All work was completed prior to introduction of formal international reporting codes, and the QP does not consider these data to be suitable for the estimation of resources.

6.2.4 *RV Tangaroa* (1975–1978)

From 1975–1978, the New Zealand Oceanographic Institute (NZOI) carried out four major site investigation cruises with *RV Tangaroa*. The cruises predominantly undertook seabed photography and seabed sampling across the Chatham Rise. Results of the cruises were reported by Cullen (1978). In an attempt to trace the extent of the sub-surface phosphorite-bearing sediments and to gauge the thickness of the deposit, cores were collected from 53 stations on the central Chatham Rise and comprised 21 piston cores, 4 gravity cores, and 28 box cores. Piston cores were collected initially using a 5.5-m-long, 76-mm-diameter barrel, with 340 kg of lead weights, then a 1.8-m-long barrel with 681 kg of lead weight to penetrate phosphorite-bearing sediments. The penetration depth of the piston cores ranged from 0.32–4.67 m. The gravity corer, with a 0.6-m-long barrel and internal diameter of 76 mm, was weighted with 91 kg of lead but never exceeded 0.25-m penetration depth. Box cores were collected using a Friedrich Leutert corer with internal dimensions of 0.225 m (width) × 0.295 m (length) × 0.47 m (height) and an effective height of 0.3 m. The maximum penetration obtained was 0.22 m, and reported phosphorite weight per cent data from the box cores ranged from 0.9%–69.9%, with an average of 19.6% (Figure 6-2) (Cullen, 1978).

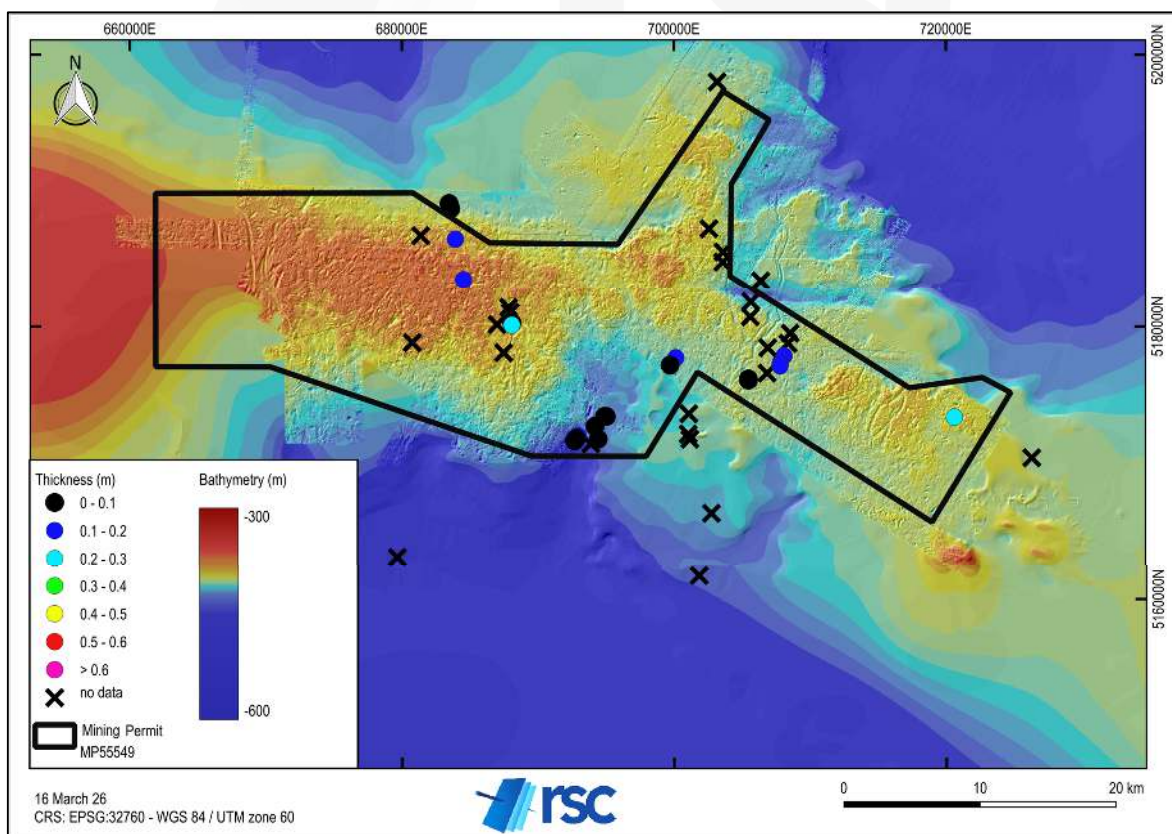


Figure 6-2: *RV Tangaroa* sample locations and reported penetration depths.

The *RV Tangaroa* sample locations were determined using satellite navigation. The estimated accuracy of this method as applied in the 1970s is ~0.25–0.5 nm (0.5–0.9 km) (Wood et al., 2003). The data presented in Cullen (1978) indicate that piston cores were geologically logged using standard logging sheets and include brief geological descriptions accompanied by percentage estimates and/or graphic logs of sand occurrence and the presence/absence of component minerals. Box core samples were analysed for their grain size distributions and phosphorite grade. No information is provided on how the phosphorite estimation was conducted. No information detailing sampling procedures or the raw data collected were available. Multiplying the reported weight percentages of phosphorite for the *RV Tangaroa* samples by the average wet density of phosphorite nodules (taken as 2.72 g/cm³ based on the most recent density data collected by CRP, Section 11.2) yields phosphorite grades up to 1,901 Ph kg/m³ and averaging 532.4 Ph kg/m³ (Figure 6-3). The QP does not consider these grades to be representative, as insufficient data are available to reliably calculate phosphorite grade and the sample data cannot be verified; the QP has reduced the SQR ranking on data collected from the *RV Tangaroa* to a level outside the ranking levels included in the resource estimation.

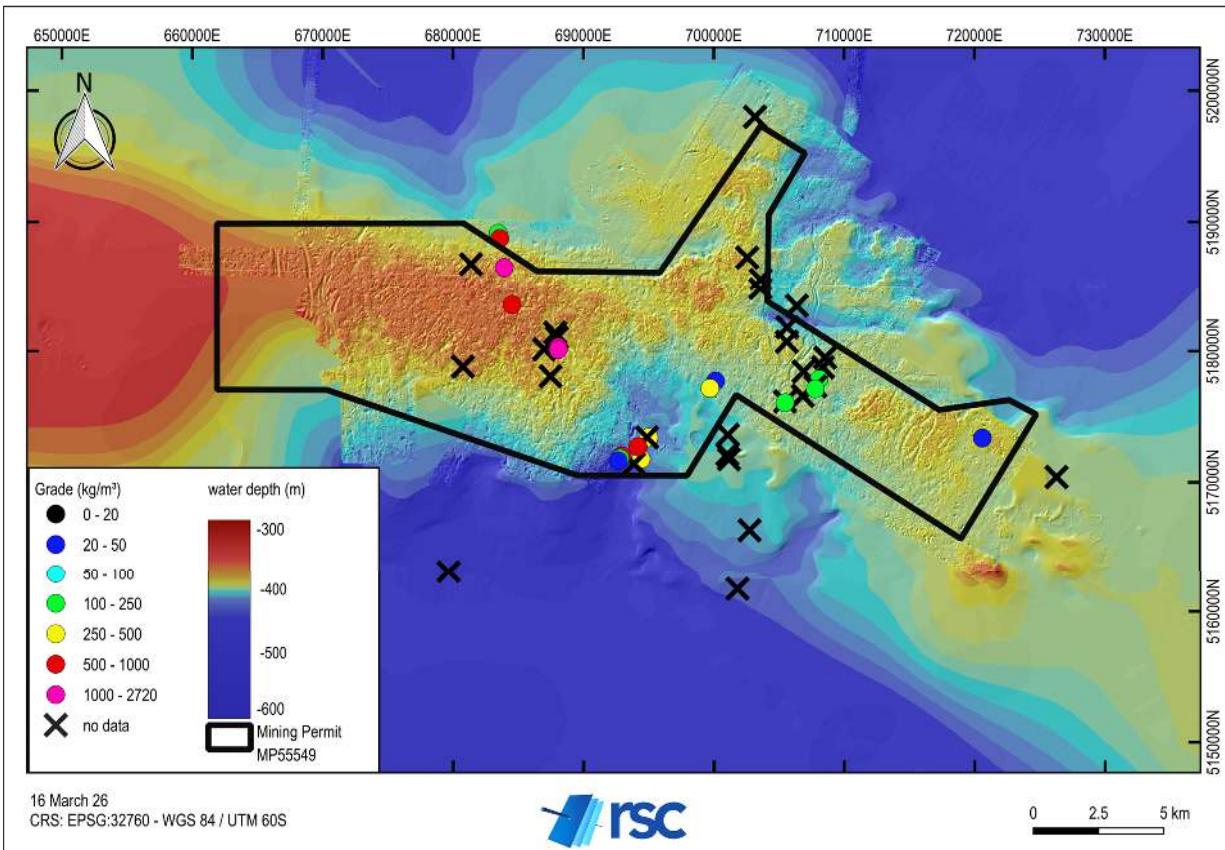


Figure 6-3: *RV Tangaroa* sample locations and updated phosphorite grades.

6.2.5 RV Valdivia (1978)

Through a government agreement between New Zealand and Germany on scientific and technological cooperation, the New Zealand Department of Scientific and Industrial Research (DSIR) and the West Germany Government collaborated on cruises by the German research vessels, *RV Valdivia* in 1978 and *RV Sonne*, in 1981.

The 1978 *RV Valdivia* cruise was the first intensive sampling and research campaign to be conducted over the Chatham Rise. The campaign was conducted in two stages in October–November 1978. Results from previous were used to select the most promising area for this survey, i.e. between 179°00' E and 179°40' E on the crest of the Chatham Rise. In total, 655 samples from 689 attempts were collected over an area of 300 km².

6.2.5.1 Sample Locations

During the cruise, sample locations were determined using a combination of satellite navigation (SATNAV) with an integrated Doppler sonar system, and a network of underwater acoustic transponder navigation (ATNAV). Eight transponders were deployed in the east of the sampling area, and three transponders were deployed in the west. The ATNAV system was used to determine the location of 647 samples, with the location of the remaining samples determined solely using SATNAV (Kudrass & Cullen, 1982). As the transponders were located using SATNAV, the overall accuracy of sample locations was estimated to be within 0.25–0.5 nm (0.5–0.9 km) (Stewart & Black, 2013; Wood et al., 2003); however, the precision of applicable sample locations relative to each other is increased by the use of the transponder network, reducing the error associated with relative sample locations to ~5–10 m (Kudrass & Cullen, 1982).

Most grab samples were taken while the ship was drifting, which resulted in an irregular pattern of sampling but allowed more samples to be collected. Wire lengths to the grab samplers were less than 10 m longer than the water depths, so the positions of the samples are approximately equivalent to the ship's position.

Even though best practice positioning available at that time was used, the QP notes the relative inaccuracy of the sample positions. Sampling from a drifting boat resulted in the sample spacing being somewhat erratic and caused data clustering issues. The sample spacing was typically 250–500 m, but locally up to 1–2 km.

6.2.5.2 Sampling Methods

The samples were typically collected using a large Van Veen grab sampler of 0.12 m³ volume, weighing ~400 kg, and having a sampling area of ~66 cm × 66 cm (Figure 6-4). Other methods of sample collection were trialled, including a smaller Van Veen grab sampler with a sampling area of ~45 cm × 45 cm, a box corer, a 3 m piston corer equipped with a pilot corer, a box core sampler, and a chain bag dredge (Table 6-1). The main issues with these methods were poor sample penetration and sample recovery. The large Van Veen grab sampler had its shortcomings, including lower penetration power into nodule-rich sediment and insufficient jaw closing power, resulting in large nodules occasionally becoming caught between the jaws, preventing complete closure of the grab sampler and causing sediment loss. However, despite these issues, it was the best of the sampling systems available on the market at the time (Hermann Kudrass, pers. comm.) and was used up until it was lost overboard when trying to collect sample 578, after which the smaller Van Veen grab sampler was used.



Figure 6-4: Large (left) and small (right) Van Veen grab samplers used to collect sediment samples aboard the *RV Valdivia*.

Table 6-1: Sampling conducted aboard the *RV Valdivia*.

Sampling Method	Attempts	Successful	Empty	Washed Out	Failed
Large Van Veen grab sampler	561	495	8	32	26
Small Van Veen grab sampler	110	105	-	4	1
Box grab sampler	8	8	-	-	-
Box corer	2	-	-	-	2
Piston corer	6	3	-	-	3
Chain bag dredge	2	-	-	-	2
TOTAL	689	611	8	36	34

Note: 'Empty' samples were those that came up empty despite no apparent equipment malfunction (assigned a phosphorite grade of 0 Ph kg/m³).

Sampling using the large and small Van Veen grab sampler involved lowering the sampler to the seafloor where, on contact with the sediment, the slackening of the cable disengaged the mechanism, holding the grab sampler jaws open. Recalling the cable would raise the outer arms of the jaws, pulling them closed before retrieving the grab sampler to the ship (Figure 6-5). This process relies on the weight of the grab sampler both to penetrate the sediment and to force the jaws to close. Weights were added to the grab sampler during the programme to improve penetration of the sand (Hermann Kudrass, pers. comm.); however, it is unclear when the weights were added during the sampling programme and which samples were affected. Flaps at the top of the large grab sampler prevented the development of a bow wave as the grab sampler was lowered and protected the sample from being washed out while retrieval was in progress.

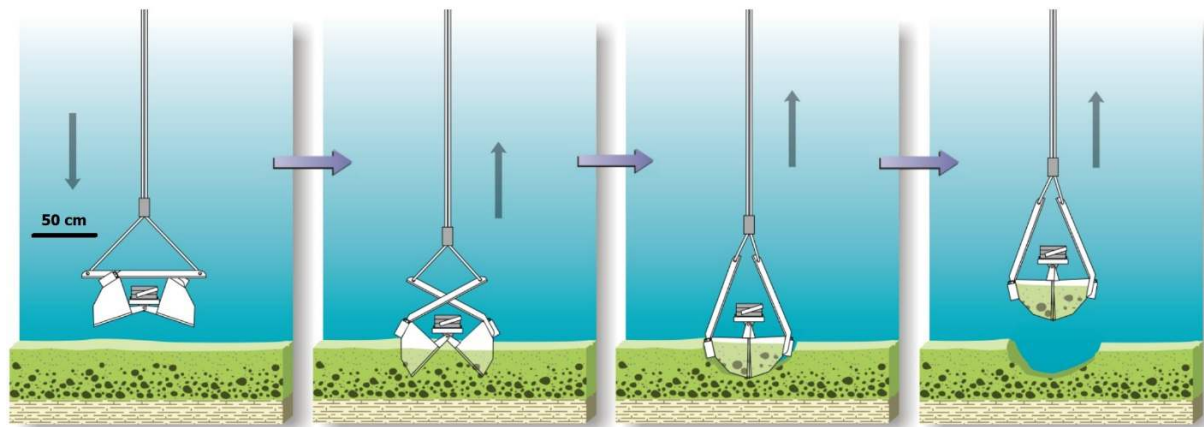


Figure 6-5: Van Veen-style sampling method.

The QP notes that most of the sampling attempts were unable to penetrate the full depth of the sand and therefore do not provide a representative sample of the entire mineralised profile. It is unclear whether the samples underwent any lateral compression during closure of the grab sampler. The QP has not made any adjustments to penetration data and has assumed that the recorded thickness of sand in the grab sampler reflects the true thickness of sediment that was sampled. However, the sampling is likely to have been slightly biased towards the collection of surface sediments due to the semi-circular cross-section of sediment a Van Veen grab sampler collects. The QP has taken these and other issues into consideration when assigning SQR values to the *RV Valdivia* samples.

6.2.5.3 Sample Preparation & Analysis

Upon reaching the deck, the grab samples were briefly described by the deck crew. The penetration depth was measured for all successful samples by accessing the samples through the top of the grab sampler and using a ruler to measure the distance from the top of the sediment to the top of the grab sampler and subtracting this from the height of the grab sampler. The volume of samples was measured by transferring them into calibrated bins. Samples were typically sieved in their entirety; however, 37 grab samples had only large (20–80 L) subsamples of their sediment sieved. No information is available on how these subsamples were extracted from the grab samples.

Sampled sediment was washed through a 1-mm screen. The volume of the >1-mm fraction was measured using the water displacement method in graduated cylinders (Hermann Kudrass, pers. comm.), and its phosphorite concentration estimated as a phosphorite volume per cent (Kudrass & Cullen, 1982). These values are reported to have been measured; however, there is some error in the relationship between penetration thickness and volume (Figure 6-6). The spread of the data suggests that one or other of the parameters may have been estimated in a number of samples, although volume estimates below the general trend of the curve may indicate sediment loss during sample handling and recovery from the grab sampler. Water-rich sediments may have been washed out while they were being retrieved from the grab sampler for measuring, resulting in a decrease in volume. Conversely, disturbance of tightly packed sediments during measuring would have resulted in an increase in volume due to loosening of the sediment causing an increase in the spacing between grains. The limited information recorded on the raw data sheets makes it difficult to determine the cause for the variation in the

sample measurements, but the QP notes it as a factor impacting on the SQR ranking of the sample, with large variance resulting in a lower rank.

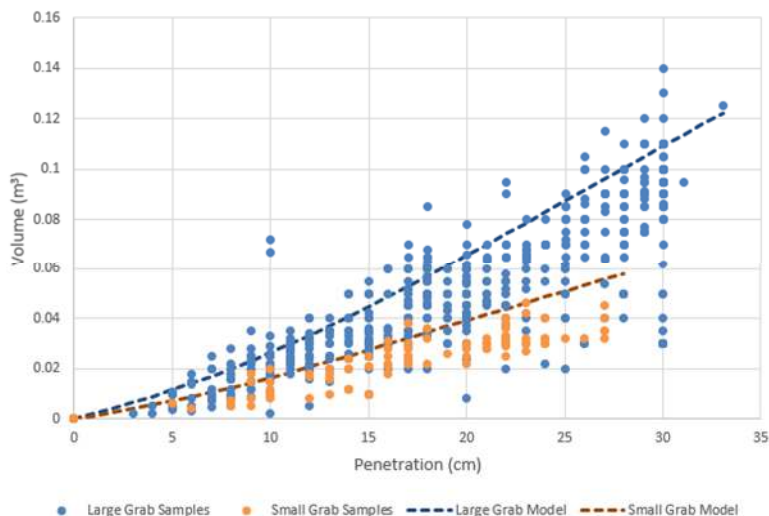


Figure 6-6: Reported penetration depth of sediment vs reported volume of sediment in *RV Valdivia* grab samples compared to modelled theoretical bucket volume-depth relationship (dotted lines).

Dried nodules from 330 of the grab samples were sieved into six fractions: <2 mm, 2–4 mm, 4–8 mm, 8–16 mm, 16–32 mm, and >32 mm. For three bulk samples, the fractions were also split, crushed, and sent for bulk chemical analysis by XRF (Kudrass & Cullen, 1982). The method used to split the samples is not recorded.

6.2.5.4 Density & Moisture Content

Density and moisture contents were determined for the total sediment as well as for the phosphorite concentrate.

Density tests on the sediment were conducted on five subsamples of bulk sediment from the *RV Valdivia* cruise. The bulk sediment samples ranged from 1.2–2.8 kg (wet weight), yielding a range in wet density of 1.62–2.06 g/cm³ and an average density of 1.92 g/cm³. Two of the samples were further measured for their dry weight, yielding dry densities of 1.45 g/cm³ and 1.53 g/cm³. Moisture content ranged from 25–29% for the bulk-sediment samples.

Density tests on the phosphorite concentrate were carried out on six grab samples and one chain bag dredge sample that were subsampled for nodules representing a range of different grain sizes. Volume and wet weights were measured to calculate their wet density. Four of the samples were further measured for their dry weight, and their dry density was calculated. The nodule samples ranged from 0.76–37.9 kg (wet weight), with a wet density range of 2.53–2.81 g/cm³ and an average wet density of 2.67 g/cm³. The four samples processed for dry density had a range of 2.52–2.73 g/cm³ and an average dry density of 2.64 g/cm³. Moisture content ranged from 1.8–5.9% for the phosphorite nodules.

The QP is unable to verify the density sampling procedure, the depth of samples within the sediment column, or the volume and weight measurement methods used to determine the above densities and moisture contents. The limited number of samples also makes it impossible to draw reliable conclusions about the uniformity/variability of the density of the Chatham

Rise phosphorite resource. Overall, sand density is strongly affected by phosphorite content, so in future sampling expeditions, the QP recommends collection of a range of samples to understand the variability of the sand density.

6.2.5.5 Data Quality

No known QC measures were applied during the *RV Valdivia* sampling, and sampling procedures are documented in research papers in summary format. After investigation of the various available reports and comments, the QP concludes that sampling procedures are likely to have been adjusted as new information came to the attention of the sampling crews.

Some noted procedures include:

- sample data were recorded on standard logs and signed off;
- samples were classified as unsuccessful if equipment failed or if significant sample loss was noted during logging of the sample (by observation); and
- geological descriptions were recorded using a prescribed set of logging codes.

6.2.5.6 Logging

Upon retrieval, samples were briefly described using a prescribed set of logging codes, then grab sampler and box core samples had their volume and/or penetration depths measured. Penetration depth and/or core length were recorded for piston cores.

6.2.5.7 Estimation of Phosphorite Grades in Samples

Available data for the *RV Valdivia* cruise include sieved sample volumes. For 37 of the samples, a sub-split was processed; therefore, for those samples, the sieved sample volume is not the same as total sample volume. For all other samples, the entire sample was sieved; therefore, the sieved sample volume is the same as the total sample volume. Available data also include the volume of the >1 mm fraction and the visually estimated percentage of phosphorite within the >1 mm fraction (these concentrates could still contain large shell fragments, etc.). This applies to all successful grab sampler and box core samples.

Phosphorite volume per cent was calculated by first multiplying the estimated percentage of phosphorite within the >1 mm fraction by the volume of this fraction which yielded the volume of phosphorite in the >1 mm fraction (i.e. excluding shell fragments, etc.). This volume was then divided by the sieved sample volume to give phosphorite volume per cent for the sieved sample. Phosphorite grade was then determined by multiplying the calculated phosphorite volume per cent by the average wet density of phosphorite nodules (taken as 2.72 g/cm³ based on the most recent density data collected by CRP, Section 11.2).

Phosphorite grade could be determined for 623 of the 689 attempted *RV Valdivia* samples for which sediment was recovered. Calculated grades vary up to 2,380 Ph kg/m³, with an average of 367.0 Ph kg/m³ (Figure 6-7). Phosphorite nodule abundance can then be determined by multiplying grade by the thickness of sand in the sample (this is equal to the penetration depth for most of the samples); however, where geological descriptions included sand thicknesses, the sand thickness values were used. For the purpose of the calculations, the penetration thickness and/or sand thickness recorded

for each sample is assumed to be equal to the true sample/sand depth of the samples, as it is unknown whether grab samples underwent any lateral compression during closure of the grab sampler. Sand thickness in the *RV Valdivia* samples varied from 2–33 cm for samples collected by grab samplers and from 12–37 cm for box core samples. Combined, these yield an average sampled sand thickness of 18 cm (Figure 6-8). Using this parameter, the *RV Valdivia* samples have a maximum nodule abundance of 285.6 Ph kg/m², with an average nodule abundance of 54.4 Ph kg/m².

In summary, the QP notes a number of concerns with the sampling process and grade estimations used on the *RV Valdivia* due to the sampling system used and measurement assumptions, in particular:

- large positional error due to SATNAV survey methods available at the time and no physical reference points in the ocean;
- sampling while drifting has created a non-uniform clustered dataset;
- the Van Veen grab sampler was mechanically controlled and lacked the ability to penetrate nodule-rich sediment;
- weights were added on the grab sampler to assist with penetration, but information was not recorded on the sample sheets, i.e. when the weight was added or how much additional weight was used;
- nodules could become caught in the Van Veen grab sampler jaws, resulting in the sample being partially or completely washed out, leading to sample bias;
- the Van Veen grab sampler size (in terms of sampled area and volume) is small for the thickness and style of deposit being sampled;
- penetration depths were taken as an observed measurement of the distance between the top of the sediment and the top of the grab sampler and are prone to human error and inconsistency between people taking the measurements for different samples;
- the precise dimensions of the grab samplers used are not known; the QP has estimated dimensions based on reported grab sampling area and photographs of the grab samplers used, as well as known volumetric capacity in the case of the large grab sampler;
- thirty-seven samples were split before being washed through the sieve, and the method of subsampling in these instances is not documented in the literature or noted clearly on the sample sheets;
- the methods of sample processing including measuring volume, subsampling and sieving are not recorded on the available data sheets; and
- the QP has assumed that the Van Veen grab samplers did not compress samples as their jaws closed and that the penetration depth recorded from the grab sampler is equal to the true sample depth.

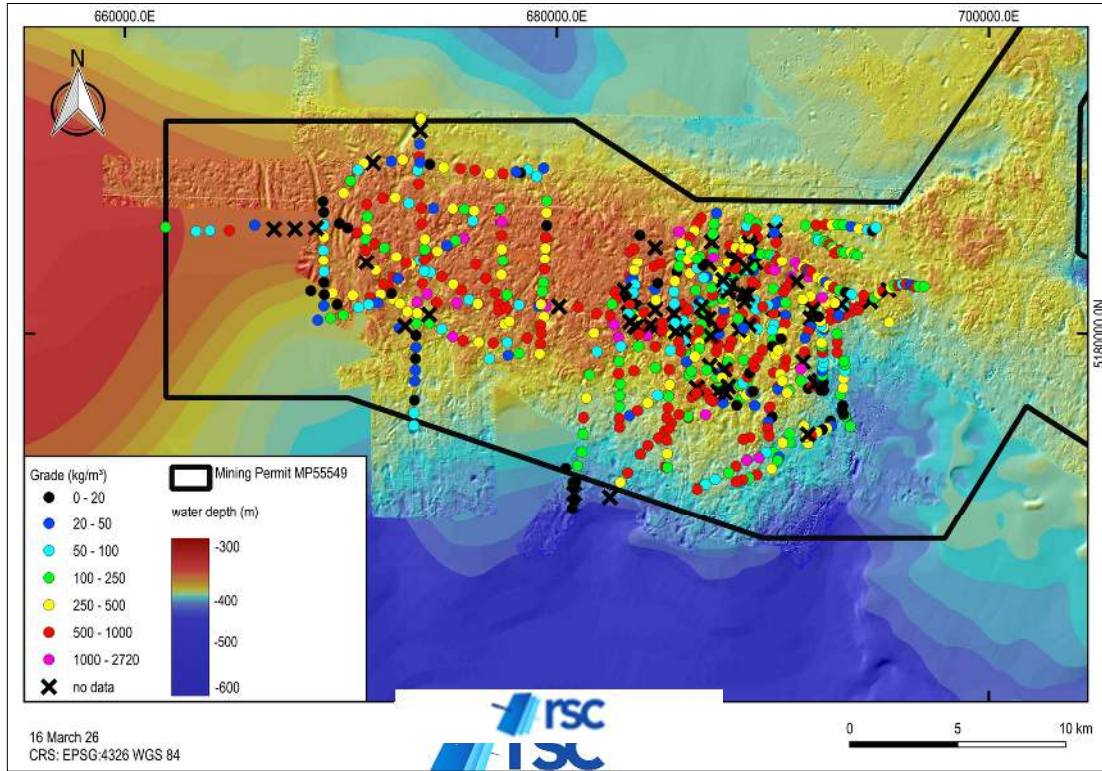


Figure 6-7: RV Valdivia sample locations and updated phosphorite grade.

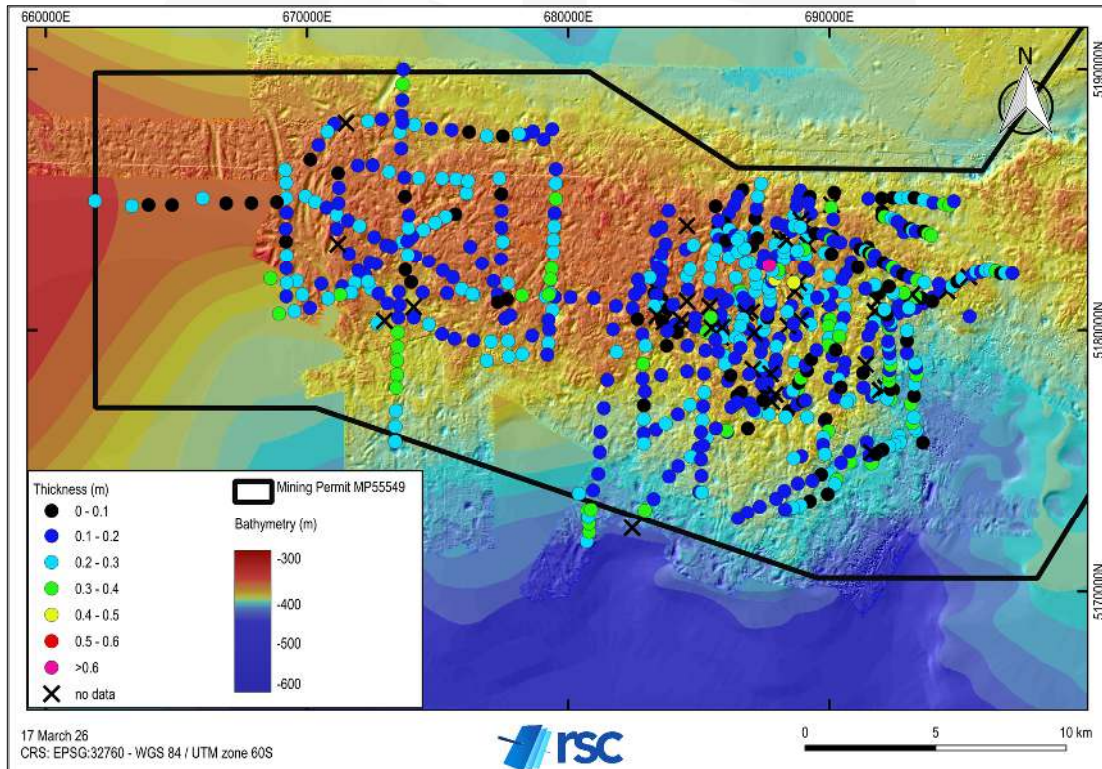


Figure 6-8: RV Valdivia true depth sample map.

In addition, historical analysis of the *RV Valdivia* phosphorite volume percentages indicated a trend towards smaller-volume samples having higher phosphorite content, and this is reflected in the calculated phosphorite grades (Figure 6-9 and Figure 6-10). This was determined at the time to reflect the poor penetration power of the grab samplers in phosphorite-rich sediment, highlighting a bias in the sampling method.

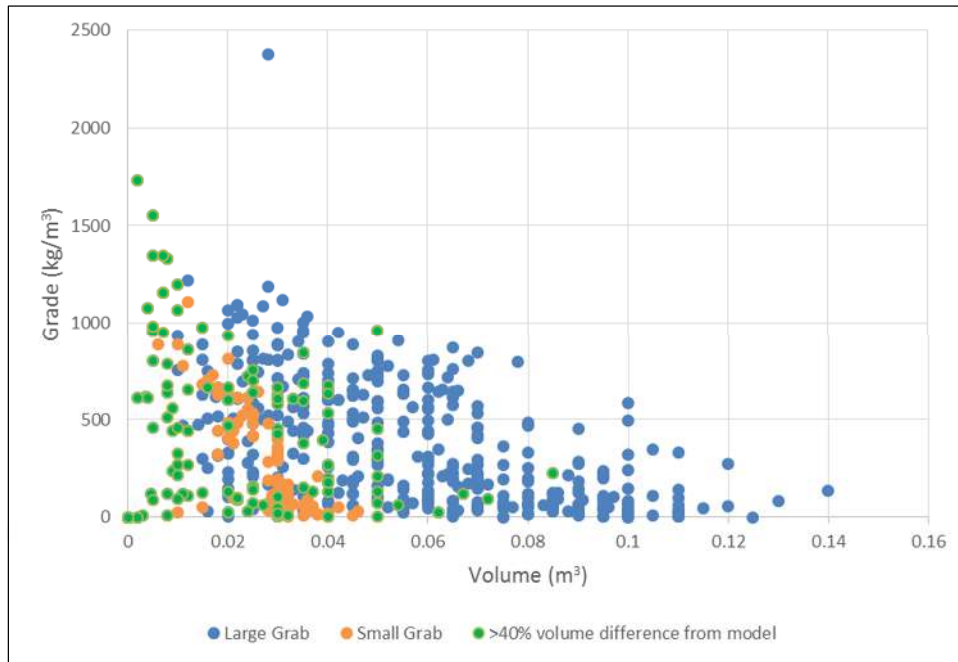


Figure 6-9: *RV Valdivia* sample volume vs calculated grade (all samples).

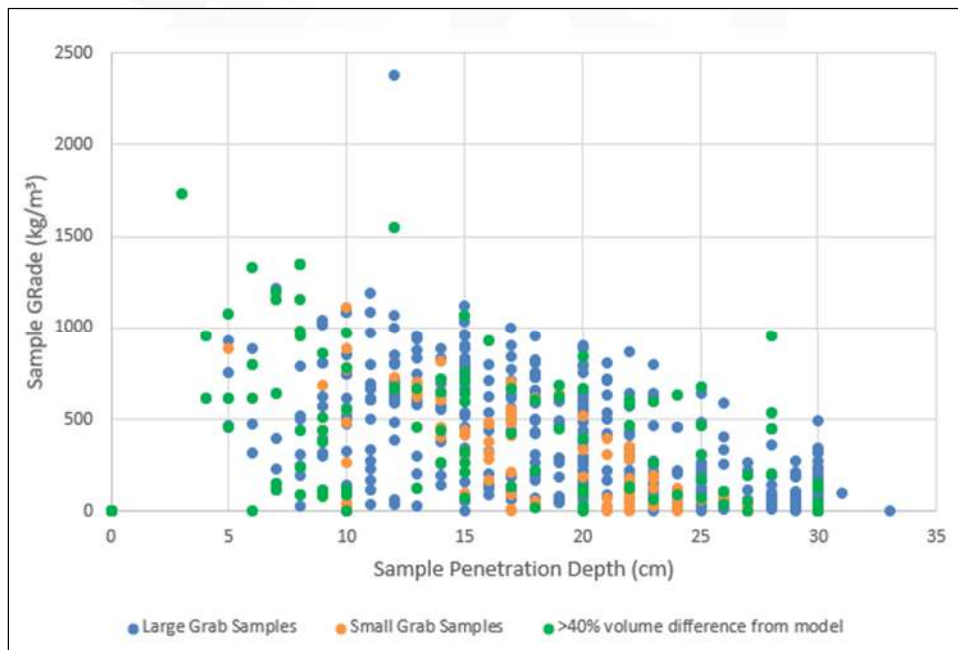


Figure 6-10: *RV Valdivia* sample penetration vs calculated grade.

6.2.6 RV Sonne (1981)

The 1981 *RV Sonne* Cruise SO-17 was the most comprehensive exploration effort to assess the Chatham Rise phosphorite nodules. It was carried out under the auspices of the Germany-New Zealand Agreement on Scientific and Technological Cooperation and of a special agreement between DSIR and BGR.

The cruise included a detailed investigation of four study areas, each 50–80 km² in area, as well as reconnaissance mapping of larger areas (~14,000 km²), to obtain an overview of the structure and phosphorite prospectivity of larger areas between 178°E and 178°W.

The areas selected for study were chosen on the basis of seafloor roughness (micro relief) determined from interpretation of seismic data (Falconer et al., 1984). A positive correlation was recognised between phosphorite nodule abundance and seafloor roughness, and the seafloor was divided into 'seismic facies', which denoted variations in roughness. The study areas were those in which the seafloor roughness was most pronounced.

In addition to oceanographic, meteorological, and geophysical data, 19 hours of video recordings of the seafloor were collected during the cruise, as well as 530 sediment samples, the vast majority taken by a pneumatic grab sampler. The maximum penetration depth of the pneumatic grab sampler was 70 cm; however, ~100% sample recovery could only be obtained down to a depth of 38 cm due to the volume capacity of the grab sampler. This was typically sufficient to penetrate the phosphorite-bearing sand as well as the top of the underlying chalk and to produce relatively undisturbed samples. The maximum sample size was 1.3 t.

The New Zealand company, Fletcher Challenge Ltd, was involved in the *RV Sonne* work and in 1981 formed a partnership with the German industrial parties. It was subsequently granted a prospecting licence for further investigation of the phosphorite deposits. Several reports were produced, detailing feasibility studies and resource estimates, but no further data collection surveys were undertaken, and the licence was allowed to lapse in 1984.

6.2.6.1 Sample Locations

The *RV Sonne* was equipped with a MAGNAVOX satellite navigation system coupled to a Doppler sonar to determine its geographic position (von Rad, 1984). Using this system a position accuracy of 200–500 m was achieved. To increase the location accuracy of samples an underwater ATNAV system consisting of 6–8 transponders was laid at a spacing of 3,000–4,000 m on the seafloor. Under favourable conditions, the system had an accuracy of 30–50 m in the central parts of the grid and 100 m near the edges. Geographical coordinates were determined by ATNAV positions and satellite fixes. With ten satellite fixes available, the accuracy of latitude and longitude estimates within the ATNAV areas was 180 m. A total of four ATNAV areas were used for the *RV Sonne* grab sampling, each using 5–8 transponders (Kudrass, 1984).

Sample positions for the *RV Sonne* and *RV Valdivia* cruises recorded in the supplied database were sourced from original hard-copy maps, digitised, and registered by NIWA. A handful of samples that did not have location data in this database were digitised using the latitudes and longitudes recorded on the raw data sheets; some samples with valid phosphorite data only had a record of local grid coordinates on the raw data sheets, and it is not known how these translate to a standard regional datum, so their sample location cannot be determined.

CRP contracted GNS Science (Institute of Geological and Nuclear Sciences Limited) to try and improve sample location accuracy using measured seafloor depths recorded at the *RV Sonne* and *RV Valdivia* sample locations, with modern bathymetry data collected on the four cruises conducted by the *RV Dorado Discovery*. Results from the work (Stewart & Black, 2013) indicate that for the *RV Sonne*, the survey position for areas 1 and 2 could not be improved, whereas *RV Sonne* 3 and 4 samples demonstrate a better correlation to bathymetry if the samples are moved 280 m northwest and 230 m southeast, respectively. The QP has not validated this work or made any related positional adjustments.

6.2.6.2 Sampling Methods

The *RV Sonne* cruise was carried out in three stages from March–May 1981. Its main objectives were to investigate the regional distribution and conduct a quantitative assessment of the phosphorite potential on the Chatham Rise, focusing on four main areas eastward of the *RV Valdivia* sampling area. A multi-method approach was used to investigate the near-surface geological structure and stratigraphy, and the facies-association, age, and genesis of phosphorite nodules and related sediments. This was done by combining continuous methods such as underwater television and photography, side-scan sonar, a 3.5 kHz sub-bottom profiler, and Huntec high-resolution deep tow boomer systems with narrow-spaced, well-positioned sediment samples. Current meters and wave riders were also employed. In 53 days, more than 2,600 km of seismic lines were traversed in four areas between 179°50' E and 178°05' W, and 550 bottom samples were obtained (von Rad, 1984). In total, 527 samples were collected over an area of ~700 km².

Most of the *RV Sonne* samples were collected using a 0.8 m³ pneumatic grab sampler that was specifically designed for the *RV Sonne* cruise (Figure 6-11). The grab sampler was built by Preussag AG and Peiner AG and weighed 1.8 t. The heavy weight of the grab sampler allowed the grab sampler to penetrate deeper into the nodule-bearing sands than grab samplers used on previous surveys. The coarse nature of the phosphorite deposits means that lighter grab samplers have difficulty penetrating past the larger nodules and consequently have reduced sample penetration and recovery; the weight and additional pneumatic closing power of 1.5 t of the *RV Sonne* grab sampler meant that many samples could be collected over the full depth of the phosphorite-bearing sand horizon and into the top of the chalk unit. However, the data indicate that even the pneumatic grab sampler experienced a reduction in penetration depth where the percentage of phosphorite nodules in the sediment was >30%, though this effect was less pronounced than with the *RV Valdivia* grab sampler (von Rad, 1984). The closing power of the *RV Sonne* eliminated the problem of large nodules wedging the jaws of the grab sampler open and causing sediment loss, as had been encountered with the *RV Valdivia* grab samples.

The nuggety nature of this type of seafloor phosphorite nodule deposit means that the larger the sample, the lower the sample variability caused by the coarse-grained nodules. The open pneumatic grab sampler sampled an area of 1.9 m × 1.06 m of the seafloor surface (2 m²). The sample collected was relatively undisturbed; however, observations of the samples in the bucket (Hermann Kudrass, pers. comm.) and the known reduction of the bucket length from 1.9 m (open) to 1.6 m (closed) indicates that samples must have been compressed during closure of the jaws. This resulted in the sediment thicknesses observed in the bucket being greater than the true in situ thickness of the sediment. The QP has used the known dimensions of the grab sampler to develop a relationship between sample penetration and volume that determines the true sediment thickness for each sample (Section 6.2.6.8).

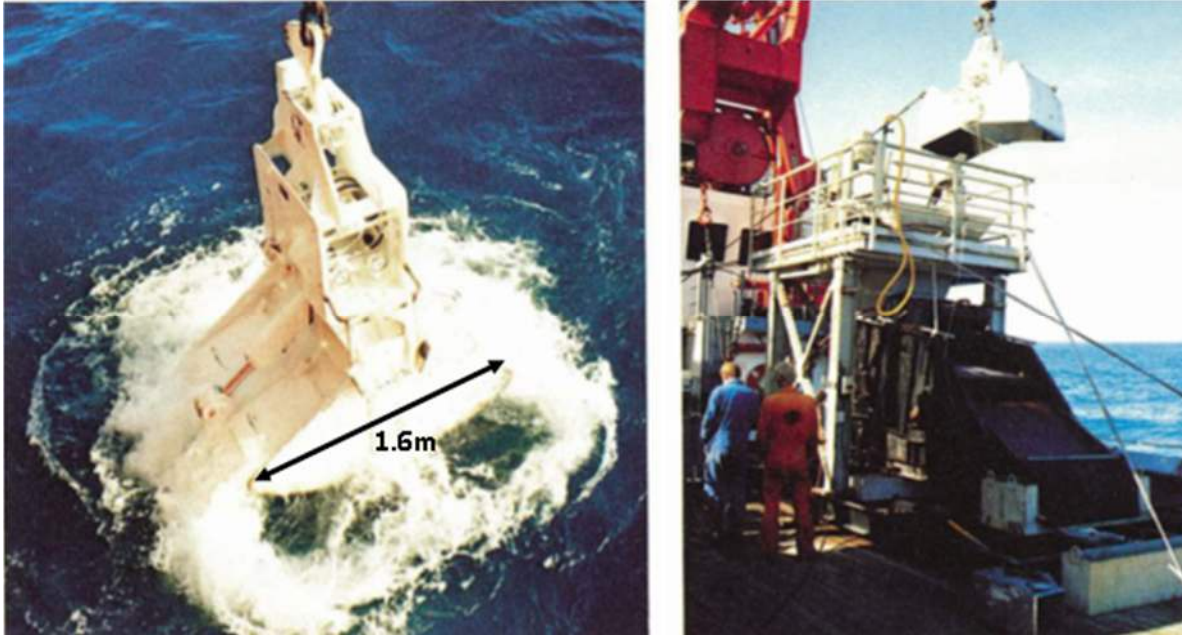
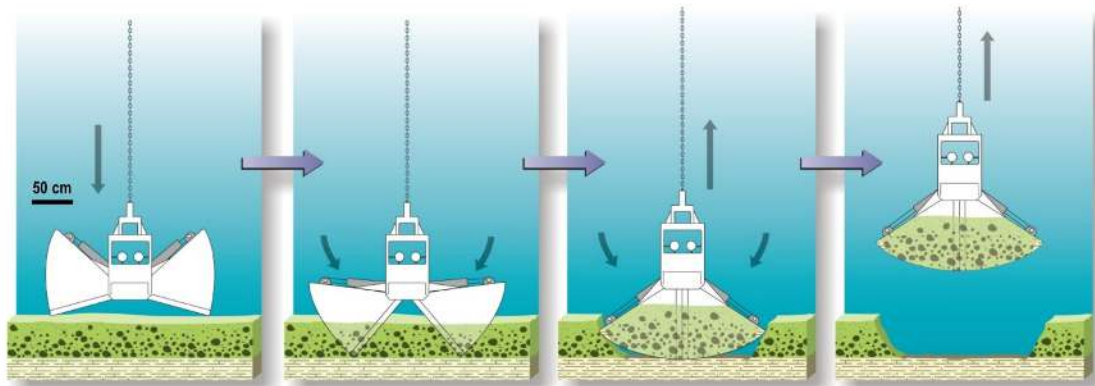


Figure 6-11: *RV Sonne* pneumatic grab sampler, hopper, and separation plant.

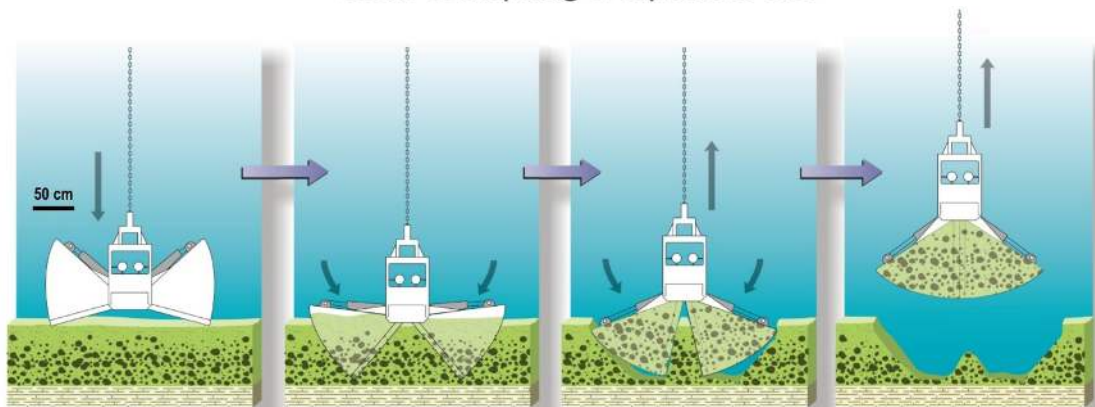
Once the pneumatic grab sampler was closed, the sample was fully enclosed and not exposed to water movement as it was retrieved from the seafloor and onto the deck of the boat. The QP does not consider sediment loss at the retrieval stage to be a significant issue; therefore, recovery in the grab sampler is likely to have been 100%, except where the bucket was completely full of sediment. In these instances, it is possible the bucket penetrated the sediment to a depth up to 70 cm, but due to its 0.8 m³ volume capacity, it could not have collected all sediment contained within its sampling area beyond a depth of 38 cm as the volume of in situ sediment exceeded the volume of the bucket. Consequently, it is inferred that all full bucket samples have an unknown sediment recovery of <100% (Figure 6-12). In addition, Kudrass (1984) notes that with increasing penetration depth, the grab sampler's own closing force caused it to lift by up to 30 cm during closure. For these reasons, it is impossible to determine true penetration depth and sample recovery for full grab samples.

While the large pneumatic grab sampler was the primary sampling tool used on the *RV Sonne*, other sampling systems used included a small Van Veen grab sampler; a 1,200 kg Kastenlot box corer (KAL) measuring 25 cm × 25 cm, with 6.5 m or 3 m long tubes; a Kiel Hammer vibrocorer (vibrating coring system; this was lost on its second deployment and could not be recovered); a 5 m long piston corer; and a chain bag dredge (Table 6-2).

With the exception of the pneumatic grab sampler, the sampling systems were unsuccessful at retrieving quality samples and further sampling attempts using the equipment were abandoned. The Kastenlot box corer was used with limited success, but there were difficulties getting the core catcher mechanism to operate properly. Several initial attempts failed to retain core. Modifications to the closing mechanism were made with limited success, and the Kastenlot sampling tool was not used further.



Grab Sampling Sequence : A



Grab Sampling Sequence : B

Figure 6-12: Interpretation of sampling process using the *RV Sonne* pneumatic grab sampler illustrating A) ~100% recovery where sand thickness <0.38 m, and B) where >0.38 m sand would result in the bucket becoming full before it had completely closed, resulting in sediment loss from the sample.

Table 6-2: *RV Sonne* sediment sampling (compiled from *RV Sonne* raw data).

Sampling Method	Attempts	Successful	Empty	Washed Out	Failed
Pneumatic grab sampler	525	515	3	2	5
Small Van Veen grab sampler	2	-	-	-	2?
Kiel vibrocorer	2	-	-	-	2
Heavy Kastenlot/box corer	14	6	2	2	4
Piston corer	3	3	-	-	-
Chain bag dredge	3	2	-	-	1
TOTAL	549	526	5	4	14

Note:

1. 'Empty' samples were those that came up empty despite no apparent equipment malfunction (assigned a phosphorite grade of 0 Ph kg/m³).

The QP regards the pneumatic grab sampling system used on the *RV Sonne* as a robust sampling system for wide-spaced sampling of seafloor phosphorite nodules. For the smaller grab, box core, and vibrocore samples, there would be increased variance between samples, and other issues, including poor penetration power into nodule-rich sediment, resulting in a sampling bias towards phosphorite-poor sediment, are likely to be encountered.

6.2.6.3 Sample Preparation & Analysis

Samples collected on the cruises were processed on board the ship. Upon retrieval of the pneumatic grab sampler, the contents of the bucket were described and the thickness of the total sediment (penetration thickness) in the bucket and thickness of the glauconitic sand component were measured (Figure 6-13). Sediment was slightly compressed by the closing of the grab sampler, and chalk was often observed to be collected in the corners of the bucket in larger samples. Consequently, penetration depth and sand thickness were recorded as the average for each parameter. Penetration depth was initially measured but later it was visually estimated based on the height of the sample within the grab sampler. This change in procedure is not documented.

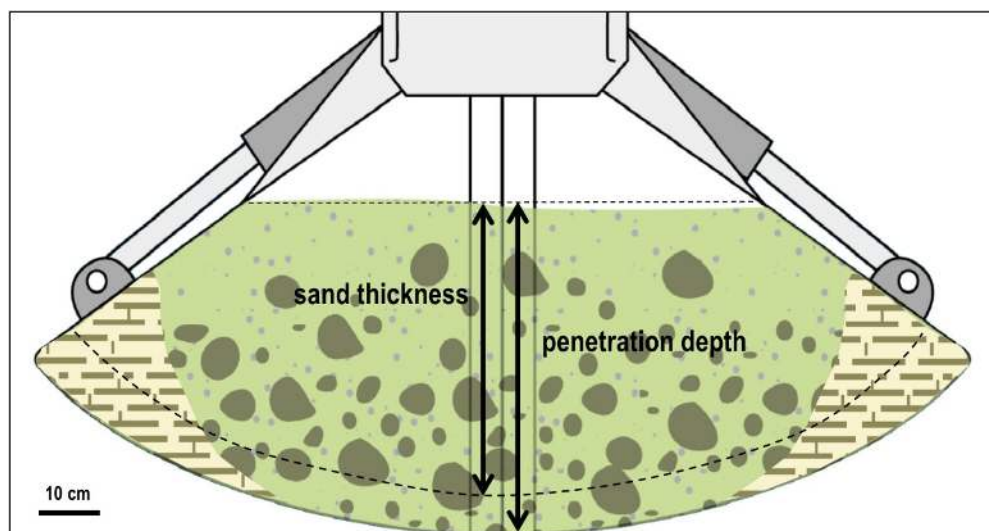


Figure 6-13: Stylised section illustrating sediment in the pneumatic grab sampler.

The bulk sample weight was initially determined using the shipboard crane by subtracting the weight of the grab sampler apparatus (1,800 kg) to determine the net sample weight; however, this proved difficult to conduct accurately due to the constant motion of the ship. Consequently, the sample processing procedure was adapted during the first cruise so that the net sample weight was estimated from the volume of sediment in the bucket. The dimensions of the bucket were measured and the volume of the bucket calculated to determine its volume in 5 cm depth increments. The penetration depths and thicknesses of the sediment, sand, and chalk (if present) were then used to determine the volume of each lithology in the sample. These volumes were multiplied by an average density for each lithology, as measured on the *RV Valdivia* (1.91 g/cm³ and 1.79 g/cm³ for sand and chalk, respectively), to estimate the weights of each component in the bucket. These weights were then summed to estimate the net weight of the grab sample (Hermann Kudrass, pers. comm.). From the raw data sheets, this transition in standard procedure appears to have taken place after sample SO069, as grab sample gross weights were no longer routinely recorded after this sample. The QP notes that this undocumented change in procedure reduces the level of confidence in the *RV Sonne* data and introduces a number of assumptions into the sample processing procedure (see section 6.2.6.6).

Small subsamples for onshore analyses were taken using a shovel, leaving the bulk of the sample for processing. Once logging was completed, the entire contents of nodule-bearing grab samples were dumped into a hopper. The hopper funnelled the sediment onto a custom-built vibrating sieve device containing an 8 mm screen and a 1 mm screen. Any material observed not to have phosphorite was discarded overboard without being sieved and the sample was recorded as not containing phosphorite. Samples were washed through the sieve and the >8 mm and 1–8 mm fractions retained; the <1 mm fraction was washed overboard (Figure 6-14).

Each retained fraction was then weighed, initially using spring weights but again this proved difficult to do accurately due to the constant motion of the ship. The procedure was again adapted, and volume-calibrated bins were used to determine the weight of the >8 mm and 1–8 mm fractions. It is not clear when this change in procedure was adopted. Trials were run to determine the graduated weight of different volumes of the separate fractions in bins and thereafter the >8 mm and 1–8 mm fractions were placed in the bins and their weight assigned based on their volume (Hermann Kudrass, pers. comm.). Unlike the calculation for net sediment weight, this process does not use a numeric assumed density; it assumes that the density of the >8 mm and 1–8 mm fractions was approximately the same.

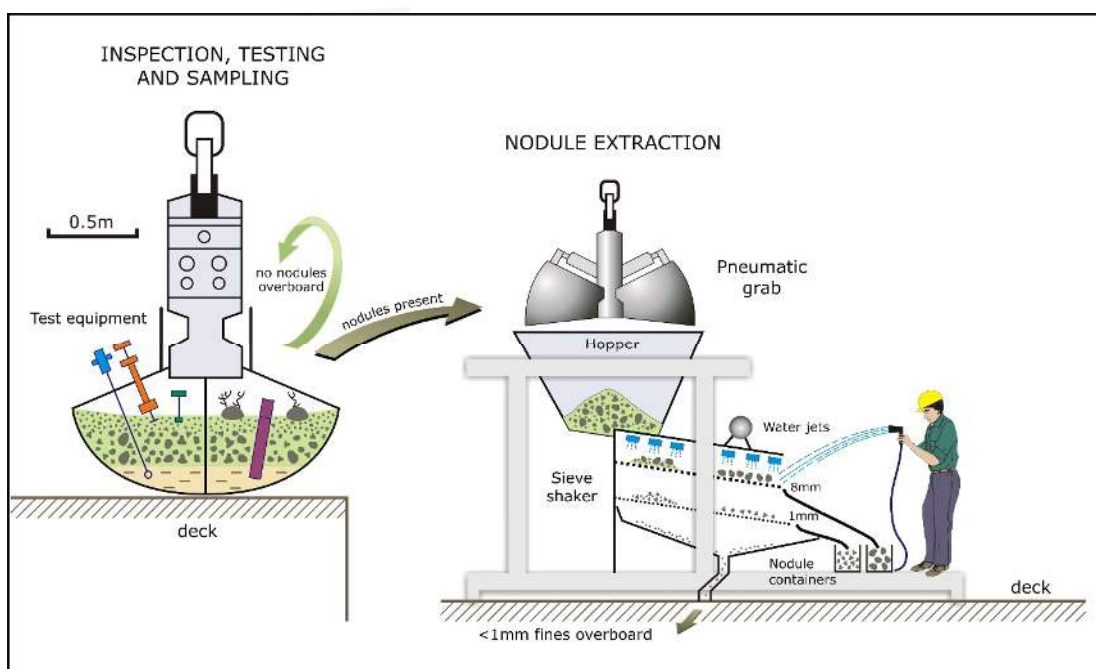


Figure 6-14: Processing of grab samples aboard the *RV Sonne* (adapted from Kudrass & Cullen, 1984).

The QP notes that most of the sieved samples had estimated phosphorite percentages in excess of 90% for both fractions, but that some were significantly lower. Fractions with less (or no) phosphorite may have had their weights overestimated unless multiple calibrated bins were used and chosen depending on the estimated phosphorite percentage of each fraction. This cannot be assessed because the process was not documented in sufficient detail.

The weight per cent of each fraction relative to the estimated total weight of the sand was calculated from the volume-calibrated kilograms of the >8 mm and 1–8 mm sieved fractions. To calculate the amount of phosphorite (kg) in each fraction,

the percentage of contained phosphorite in each fraction was estimated visually and multiplied by the weight of the fraction. These weights were summed to determine the total amount of phosphorite (kg) in each sample.

The QP notes that a visually estimated phosphorite percentage is equivalent to a volume per cent, and therefore cannot be used to calculate contained kilograms of phosphorite from a sample or sieved fraction weight, without assuming that the density of all the constituents is similar.

While these values were recorded for each sample that was sieved, the volume of the >8 mm and 1–8 mm fractions was not always recorded. Consequently, contained phosphorite for each fraction cannot be recalculated if and when detailed density data are obtained in the future for sand with varying proportions of contained phosphorite. Therefore, the weight of each sieved fraction was accepted as is by the QP and forms the basis of all subsequent grade estimates (Section 6.2.6.8).

6.2.6.4 Sediment Density & Moisture Content

Density and moisture content testwork was completed on 0.1 m³ samples taken from the grab sample (Table 6-3). The weight was assessed as the triple beam soil test balance, and the volume by means of water displacement in measures (Meyer & Toan, 1984). For moisture content, Meyer and Toan (1984) state that sediment samples were dried over 24 hours at 100°C.

Table 6-3: *RV Sonne* density and moisture content (Meyer & Toan, 1984).

Sediment	Sample	Wet density (t/m ³)		Dry density (t/m ³)		Moisture (%)	
		From-to	Average	From-to	Average	From-to	Average
Silt/sand, upper 10cm	33	1.51–1.77	1.64	0.85–1.28	0.98	50–82	68
Sand from 10–50 cm	24	1.59–1.99	1.72	0.91–1.45	1.15	32–74	51
Ooze	13	1.69–1.92	1.81	1.16–1.4	1.27	35–54	43

6.2.6.5 Phosphorite Nodule Density & Moisture Content

The density of phosphorite nodules was tested from different size fractions. Meyer and Toan (1984) do not explicitly state whether the nodules were treated in the same manner as sediment samples. The wet density of phosphorite nodules ranges from 2.55–2.96 g/cm³, with an average of 2.76 g/cm³. The density increases with increasing nodule diameter due to larger nodules having lower P₂O₅ and higher CaCO₃ contents (von Rad & Rösch, 1984). Moisture contents vary from 2–7%, being higher in larger nodules.

For the purpose of grade estimations calculated during the sampling process on the ship, Kudrass used the *RV Valdivia* wet density of 2.65 g/cm³ for phosphorite nodules, 1.91 g/cm³ for the glauconitic sand (containing phosphorite), and 1.79 g/cm³ for the chalk. The QP notes that due to the significant difference in densities between the sands and phosphorite nodules in the recovered samples, true density would vary considerably depending on the proportions of each fraction. This is likely to cause an underestimation of phosphorite grade as the phosphorite content increases.

Table 6-4 lists the nodule size range and wet density for 11 values (nine stations, two have two size ranges) and a value for each of Areas A, B, C, and D. It is not clear whether the area results are averages. It is also not clear whether reporting a

size range for each station implies that the single density value is an average of several samples or just a single nodule with a shape variation measured.

Table 6-4: Wet densities of phosphorite nodules (Meyer & Toan, 1984).

Point/Survey Area	Size (mm)	Wet Density (t/m ³)
149	7–53	2.83
153	1–8	2.61
153	>8	2.69
156	13–37	2.83
212	30–40	2.65
216	>8	2.80
351	70	2.59
354	9–37	2.96
387	32	2.55
388	6–20	2.77
388	9–26	2.76
Area A	7–19	2.90
Area B	2–19	2.86
Area B	7–19	2.82
Area C	19–37	2.79
Area D	26–53	2.71

6.2.6.6 Data Quality

The work carried out on the *RV Sonne* was the most controlled of all cruises, with a number of forms, procedures, and methodologies described in personal notebooks, reports, and scientific literature. The number of operating procedures is also evident from the log sheets. Adjustments were made during the sampling programme, and the majority of these were documented. Quality was controlled through these procedures, and the accuracy and bias of estimates were largely controlled through the various systems in place. Duplicate sample information was not collected; therefore, the QP cannot comment on the precision of the sampling process.

6.2.6.7 Logging

When the grab sampler was lowered onto the deck, the sample was initially inspected by opening lids on top of the grab sampler. From here, the surface of the sample could be observed, the penetration depth of sediment in the grab sampler measured, and biota noted. The presence and position of nodules was determined and recorded in a simple graphic log and the geology of each sample briefly described. The vertical thickness of sand and chalk was estimated either by digging into the sample, or by observing the cross-section of coherent samples upon opening of the bucket, which could be paused at any time using the pneumatic controls (von Rad, 1984). Soft samples made estimates of sediment thickness less reliable. Initially, these measurements were conducted using tape measures; however, as the sampling campaign continued, the depth estimates were estimated from observations.

The QP notes that the depth measurement process was not optimally controlled and could have been prone to errors. These measurements have some influence on the sample volume estimates and eventual estimation of the samples' true thickness.

From sample SO103 onward, shear vane measurements were conducted through the lids on top of the grab sampler, but the QP is of the opinion that these measurements may not be reliable due to the observed and/or inferred compaction of the sediments as they were collected by the closing of the grab sampler.

6.2.6.8 Estimation of Phosphorite Grades in Samples

Phosphorite nodule abundance was expressed on the original logging sheets as phosphorite kilograms per square metre (Ph kg/m²). As described above, the phosphorite content was estimated from 1–8 mm and >8 mm grain size fractions separated from the whole grab sample. These sieved fractions were either weighed or had their weight estimated from the volume measurements taken from a calibrated container. The phosphorite per cent was then estimated for each retained sieved fraction and used to calculate the contained kilograms of phosphorite in each sample. This value, though not recorded on the shipboard analysis raw data sheets, was divided by the assumed sampling area of the grab sampler in order to calculate phosphorite nodule abundance.

The open grab sampler has a sample area of 1.90 m × 1.06 m (2 m²). According to Kudrass (1984), the grab area was reduced for large volume samples due to the inferred sediment loss during collection of full grab samples (Figure 6-12). When the volume of recovered sediment was less than 0.4 m³ (half grab sampler volume), the sample area for grade calculation was reportedly kept at 2 m² but reduced to a minimum of 1.6 m² for samples up to 0.8 m³ volume (a full grab sampler volume). After thoroughly reviewing the entire *RV Sonne* dataset, the QP notes that this calculation had not actually been applied on the log sheets or in the database, with almost all grade calculations using the internal area of the closed grab sampler, 1.58 m², irrespective of sample volume.

The QP reviewed the grade calculations and re-estimated the *RV Sonne* grades using a volume-penetration relationship based on the volume of the grab sampler and penetration depth of the sediment. Based on the grab sampler specifications, a detailed 3D model of the closed grab sampler was generated and the volume calculated in 1 cm vertical increments (Figure 6-15). These were compared to the recorded penetration depths of total sediment and thickness of sand for each sample in order to calculate the volume of sand in each sample. As previously described, the amount of phosphorite (kg) in each sample was calculated from the estimated percentage of phosphorite and volume-calibrated weight of the 1–8 mm and >8 mm sieved fractions. The QP calculated the phosphorite grade (kg/m³) by dividing the total calculated phosphorite (kg) by the calculated volume of sand (m³) in each sample. This yielded grade ranges up to 2,680 Ph kg/m³, with an average of 236.4 Ph kg/m³. As with the *RV Valdivia* data, higher grades are often in close proximity to lower grade samples, highlighting the short-range variability of phosphorite grade (Figure 6-16).

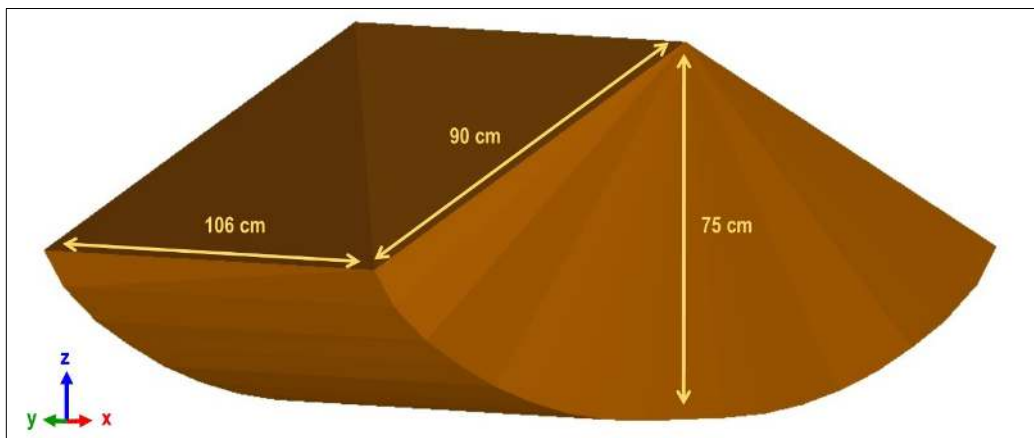


Figure 6-15: 3D model of the *RV Sonne* pneumatic grab sampler volume used to estimate bulk sample and sand volume from recorded penetration depths and sand thicknesses.

The QP has concerns about the accuracy of grades calculated using the *RV Sonne* data due to the assumption that all the samples have the same density that is inherent in using volume-calibrated bins to estimate the weight of the 1–8 mm and >8 mm sieved fractions. Due to the contrast in the average density (wet) of glauconitic sand (1.91 g/cm^3) and phosphorite nodules (2.72 g/cm^3), the density of samples would be expected to vary between these values depending on phosphorite content.

The QP notes that penetration depths are based on the average thickness of sediment in the bucket, but that sediment thickness varied across the cross-section of the bucket due in part to natural variation in the sediment morphology and also as a result of compression of the sampled sediments as the grab sampler closed. Consequently, volume calculations based on penetration depth, while considered to be a good approximation, are not considered optimal. The QP also notes that grades based on this calculation are only valid for samples that did not completely fill the grab sampler. In instances where samples did fill the grab sampler (taken as any penetration depths recorded as >60 cm or >70 cm or more), the point during bucket closure at which the bucket became full and how much sediment from the original 2 m^2 sampling area was left behind are not known. While penetration depth can still be used to calculate the volume of these samples, it must be noted that such samples potentially have recoveries that are significantly less than 100%, and that samples will also be biased towards collecting near-surface sediment. Consequently, samples representing a full grab sampler have been given a lower SQR for the purposes of resource modelling.

To calculate phosphorite nodule abundance from the *RV Sonne* samples, the QP had to determine the true thickness of the sampled sand. Due to the compression of the sampled sediment during bucket closure, this cannot be taken as the penetration depth. The QP calculated the depth based on the assumption that the grab sampler was able to sample 100% of the sediment contained within the 2 m^2 area of its open jaws down to a depth of 38 cm. Beyond this depth, the volume of *in situ* sediment within the open area of the grab sampler would exceed the capacity of the bucket and result in increasing sediment loss with greater sampling depth. By comparing the volume of *in situ* sediment in 1 cm increments with the 1 cm incremental cumulative volumes previously determined for the grab, it was possible to generate a conversion table for penetration depth to true depth of sediment for the *RV Sonne* grab sampler (Table 6-5). Using this conversion, the true

thickness for all successful *RV Sonne* samples averages 23 cm (Figure 6-17). However, due to the volume capacity of the grab sampler, true thickness >38 cm cannot be determined because of the necessity of sediment loss during sample collection; therefore, true thickness for full buckets has been capped at 38 cm.

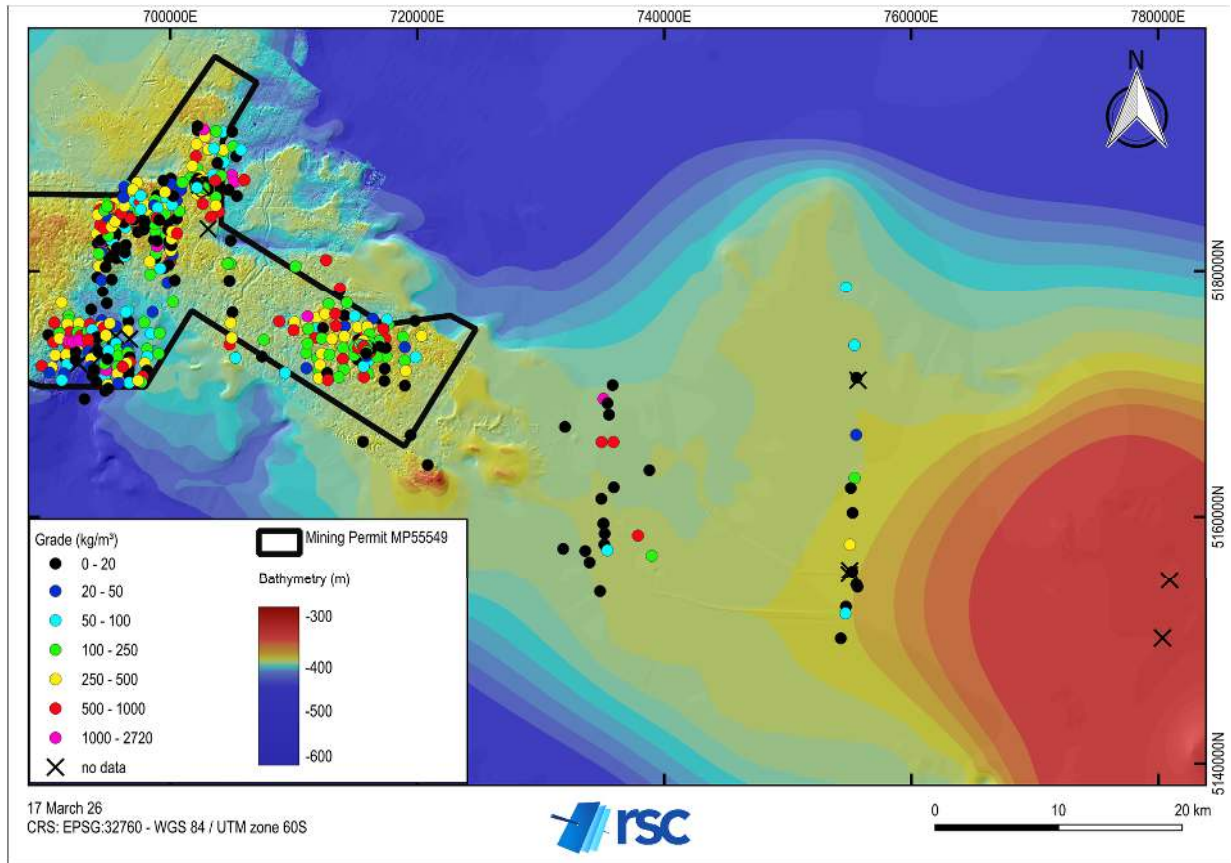


Figure 6-16: *RV Sonne* sample locations and updated phosphorite grade.

Table 6-5: Conversion table for penetration depth to true depth of sediment for *RV Sonne* samples.

Penetration Depth (cm)	True Thickness (cm)	Penetration Depth (cm)	True Thickness (cm)	Penetration Depth (cm)	True Thickness (cm)
0	0	26	15	52	33
1	0	27	16	53	33
2	0	28	17	54	34
3	1	29	17	55	34
4	1	30	18	56	34
5	2	31	19	57	35
6	2	32	20	58	35
7	2	33	21	59	35
8	3	34	22	60	36
9	4	35	22	61	36

Penetration Depth (cm)	True Thickness (cm)	Penetration Depth (cm)	True Thickness (cm)	Penetration Depth (cm)	True Thickness (cm)
10	4	36	23	62	36
11	5	37	24	63	36
12	5	38	25	64	37
13	6	39	25	65	37
14	6	40	26	66	37
15	7	41	27	67	37
16	8	42	27	68	37
17	8	43	28	69	37
18	9	44	29	70	38
19	10	45	29	71	38
20	11	46	30	72	38
21	11	47	30	73	38
22	12	48	31	74	38
23	13	49	31	75	38
24	13	50	32		
25	14	51	32		

The QP notes that the assumption of 100% recovery for samples down to a depth of 38 cm within the grab sampling area of 2 m² may not be accurate due to the slightly curved nature of the grab sampler jaws (Figure 6-12). The determination of true depth from the penetration depth of samples similarly assumes that, though the sediments are compressed, they do not undergo a net change in volume during sample collection as the thickness of the sample in the grab sampler increases vertically to accommodate the horizontal compression.

The phosphorite nodule abundance can be determined by multiplying true depths by the grade of the *RV Sonne* samples. The nodule abundances range up to 252.9 Ph kg/m² and average Ph 34.6 kg/m².

In addition to determining true thickness of sand for the *RV Sonne* samples, the QP attempted to gauge the vertical variation in phosphorite content by assessing the graphic logs recorded for the grab samples. The logs simplify the sediment contained in the grab sampler into horizons, graphically code them according to whether the sediment comprises chalk, sand containing no visible phosphorite, sand with dispersed phosphorite, or sand with concentrated phosphorite nodules (Robin Falconer, pers. comm.) and record the depth to the top and base of the horizons in the grab sampler. The QP digitised the graphic logs for the grab samples and adjusted the depths to horizons using the same conversion table as that used for determining the true depth of samples (Table 6-5). The total contained phosphorite (kg) for each sample was then divided by the total thickness of phosphorite-bearing sand in the samples, as determined from the graphic logs, to determine the average phosphorite content of the horizons in 1 cm increments. These were summed as appropriate to determine the contained phosphorite in the sand over 5 cm depth ranges, using the calculated true depth and thickness of the phosphorite-bearing horizons as a reference. The average calculated contained phosphorite (kg) across all *RV Sonne* samples is presented in Table 6-6. While the graphic logs indicate that the phosphorite distribution is vertically variable within the

phosphorite-bearing sands, this analysis further suggests that phosphorite is most concentrated in the upper parts of the sediments. The QP notes that this analysis assumes that the phosphorite is evenly distributed within the graphically logged phosphorite-bearing horizons, and is also susceptible to the surficial sediment sampling bias exhibited by other sampling equipment (Section 6.2.5.7). However the 1.5-t closing power and resultant greater penetration power of the pneumatic grab sampler means it is less susceptible to this bias, as indicated by the lack of an obvious strong inverse relationship between sample penetration depth and calculated grade (Figure 6-18). This suggests the pattern of phosphorite distribution indicated by the graphic log data, though imprecise, is valid.

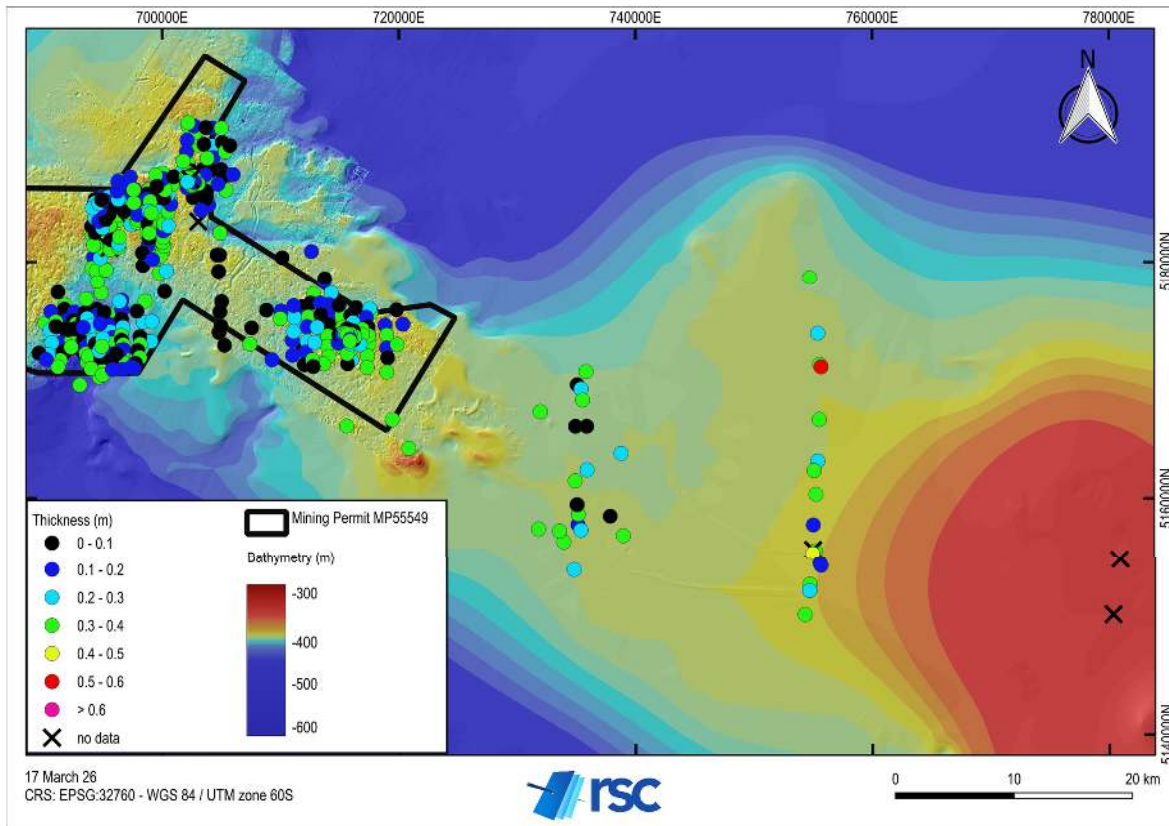


Figure 6-17: *RV Sonne* sample sand true thicknesses calculated from the recorded penetration depth and sand thickness of samples and the modelled internal volumes of the pneumatic grab sampler.

Table 6-6: Average phosphorite content calculated for true sand depth ranges from *RV Sonne* graphic logs.

Depth range	0–5 cm	5–10 cm	10–15 cm	5–20 cm	20–25 cm	25–30 cm	30–35 cm
Average phosphorite content (kg)	20.5	11.6	9	6.6	5.24	3.9	2.7

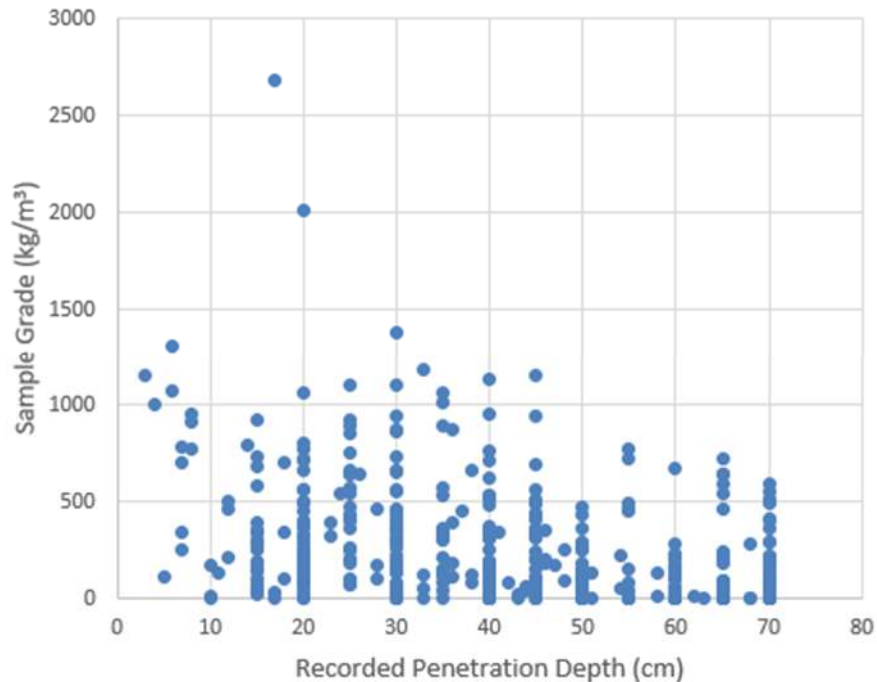


Figure 6-18: *RV Sonne* sample penetration depth vs calculated grade.

For the purposes of assigning an SQR to the *RV Sonne* samples, the presence of chalk at the base of the sediment in the bucket is taken as an indication that the grab sampler has sampled the full thickness of the nodule-bearing glauconitic sand. Where no chalk is seen, it is unknown whether the full sand profile has been sampled. Where the grab sampler was full of sediment (0.8 m³), it is inferred to have sampled depths ≥ 0.38 m and assumed that sediment recovery was <100%. For these reasons, it is impossible to determine true penetration depth and sample recovery for full grab samples.

Overall, the QP considers the pneumatic grab sample data from the *RV Sonne* to be largely representative for the purpose of resource estimation, based on:

- the ability to collect a large sample volume (up to six times larger than the Van Veen-style sampler used on the *RV Valdivia*), and the ability to collect relatively undisturbed samples, as this decreases the volume-variance issue;
- pneumatic jaws mean that large nodules do not prevent the grab sampler from closing completely, avoiding sample loss experienced by grab samplers with less closing power;
- pneumatic jaws allow the grab sampler to dig into the sand under its own weight and penetrate up to 70 cm depth, and can theoretically achieve 100% recovery down to 38 cm depth, therefore sampling the entire sand profile in most cases;
- sample penetration, sample weights, sieved weights, and phosphorite per cent of sieved fractions are well documented on sample sheets; and
- sampling procedure is documented.

However, THE QP notes the following concerns for potential sources of sample bias and errors for the *RV Sonne* grab sampler data:

- potential for positional error due to survey methods available at the time (SATNAV) and no physical reference points in the ocean (however, sample positions relative to each other are acceptable in the case of ATNAV-located samples);
- penetration depths and sand thickness were taken as observed measurements determining the distance between the sediment and the top of the grab sampler;
- densities used in the *RV Sonne* sand/chalk grab sampler volume calculations are based on results from the *RV Valdivia* and may not be representative;
- sieve weights were estimated using a calibrated volume that was determined by estimating the number of samples at the beginning of the survey for both weights and volumes and applying that relationship to all subsequent samples; and
- phosphorite per cent is taken as an observed measurement and open to variability between assessors.

The QP has made the following assumptions when recalculating phosphorite grades from the *RV Sonne* data.

- The QP has estimated the volume of the grab based on design configurations documented in ship notes from Dr Hermann Kudrass and Dr Robin Falconer.
- The QP has assumed that the volume cut into the seafloor with the sampling method is a vertical-sided cut, equal depth across the sample, and no curved edges or central ridge are left behind where the jaws close.
- The QP has assumed 100% sample recovery for samples coded as 'successful', partial recovery for samples coded as 'washed out', and 0% recovery for samples recorded as 'failed'.

6.3 Production History

At the effective date of the Report, there had been no commercial production of nodules from the Project area.

6.4 Historical Mineral Resource Estimates

The QP is not aware of any historical estimates for the Project classified in accordance with NI 43-101 and the CIM, or any other formal international reporting code.

7. Geological Setting & Mineralisation

7.1 Regional Geology

The geological history of the Chatham Rise dates to the Permian–Triassic (300–200 Ma), when a thick turbiditic sequence was deposited in a subsiding trough on the Pacific margin of Gondwana (Sporli, 1980). These rocks were later involved in the second episode of the Rangitata Orogeny in the Early Cretaceous (Wood et al., 1989), which resulted in an east–west structural grain defined by half-graben development in response to rifting in the Bounty Trough to the south (Figure 7-1), with *en echelon* stepping of the associated faults. Minor movement occurred on the same faults during the Cenozoic. Movement along similar-aged north-striking sinistral transcurrent faults resulted in the current geometry of the Chatham Rise (Wood et al., 1989).

A major unconformity overlying the Late Cretaceous to Early Palaeogene graben fill can be observed in most seismic profiles from the *RV Sonne* (Figure 7-1) (Falconer et al., 1984). This unconformity represents a period of erosion, non-deposition and slow subsidence, before the nano oozes and chert layers accumulated during the Eocene–Oligocene (Figure 7-2, Kudrass & von Rad, 1984). Sedimentation from pelagic material formed nano oozes until rapid ocean cooling during the Mid Oligocene, which resulted in changes in the foraminiferal and nanoplankton associations (Burns, 1982). On the crest of the rise, late Cretaceous sediments are typically <300 m thick, suggesting accumulation rates of <5 m/Myr (Burns, 1984).

Seismic profiles indicate intense block faulting (with throws up to 65 m) and by the end of the Cretaceous, 1,000–2,500 m of sediments were deposited in newly formed half-grabens, with the thickest accumulations to the west (Wood et al., 1989). After a depositional hiatus and erosion during the Late Oligocene, deposition of foraminiferal ooze resumed in the Early Miocene, with increasing thickness towards the flanks of the Chatham Rise (Kudrass & von Rad, 1984).

In the mid-Cretaceous (100 Ma), the first phase of Gondwanan break-up resulted in the regional formation of isolated lacustrine depositional centres that formed in east-striking half-grabens. Initial terrigenous graben fill was followed by the deposition of shallow-marine sediments. Subduction occurred along the northern margin of the Chatham Rise until its collision with the Hikurangi Plateau. The Bounty Trough, which represents a failed extension of the New Caledonia and deep-water Taranaki basins, forms what is now the southern margin of the Chatham Rise (Falconer et al., 1984).

Following the cessation of faulting by the Late Cretaceous (66 Ma), a period of terrestrial subsidence and shallow-marine deposition during the Palaeocene (65–55 Ma) was punctuated with shallow-marine volcanism. Igneous activity persisted throughout the Cenozoic on the Chatham Islands, and igneous features of Cretaceous and Cenozoic age can be identified in seismic profiles (Figure 7-2, Falconer et al., 1984).

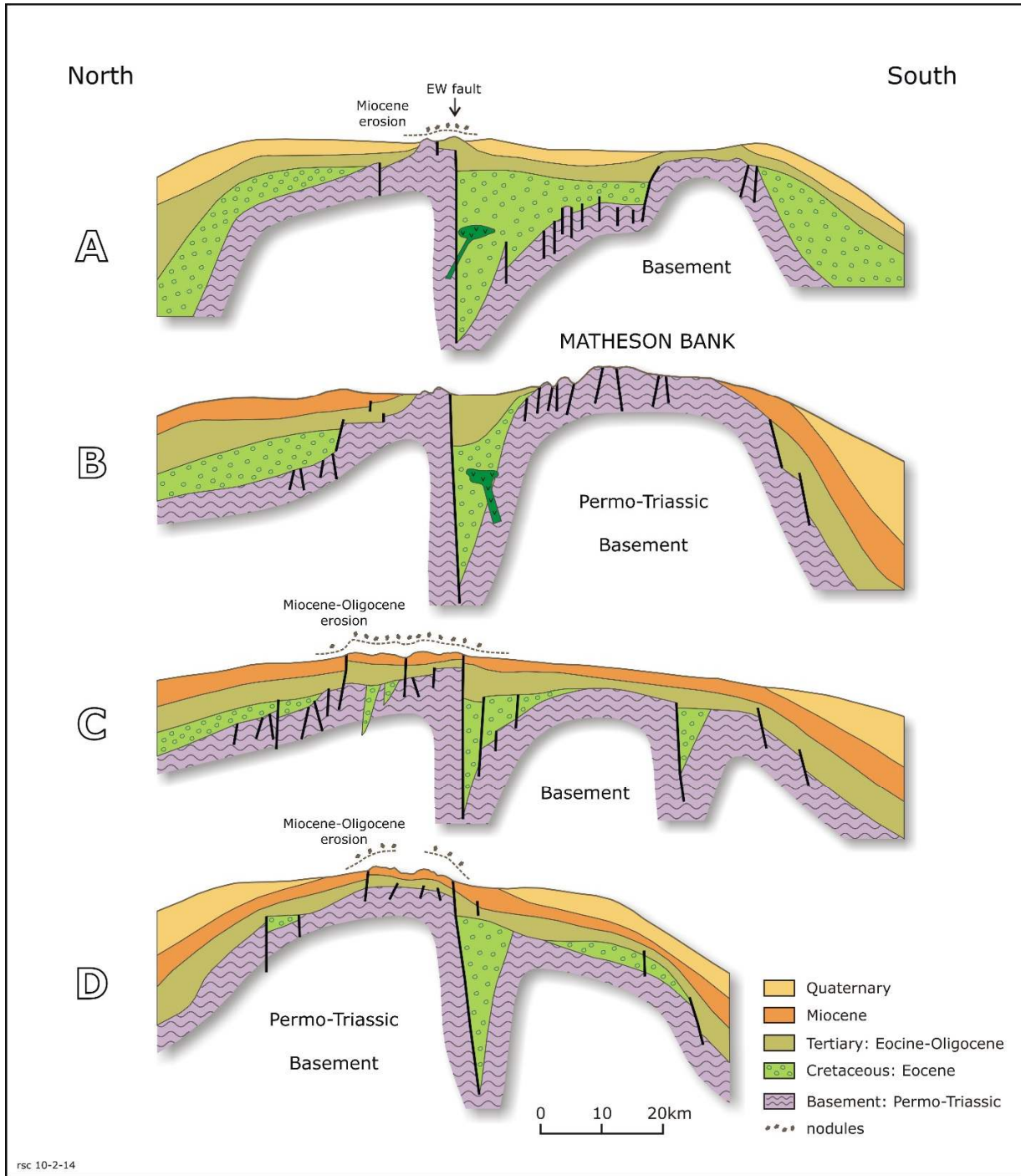


Figure 7-1: Sectional interpretation of the development of the Chatham Rise and associated phosphorite deposition (adapted from Falconer et al., 1984).

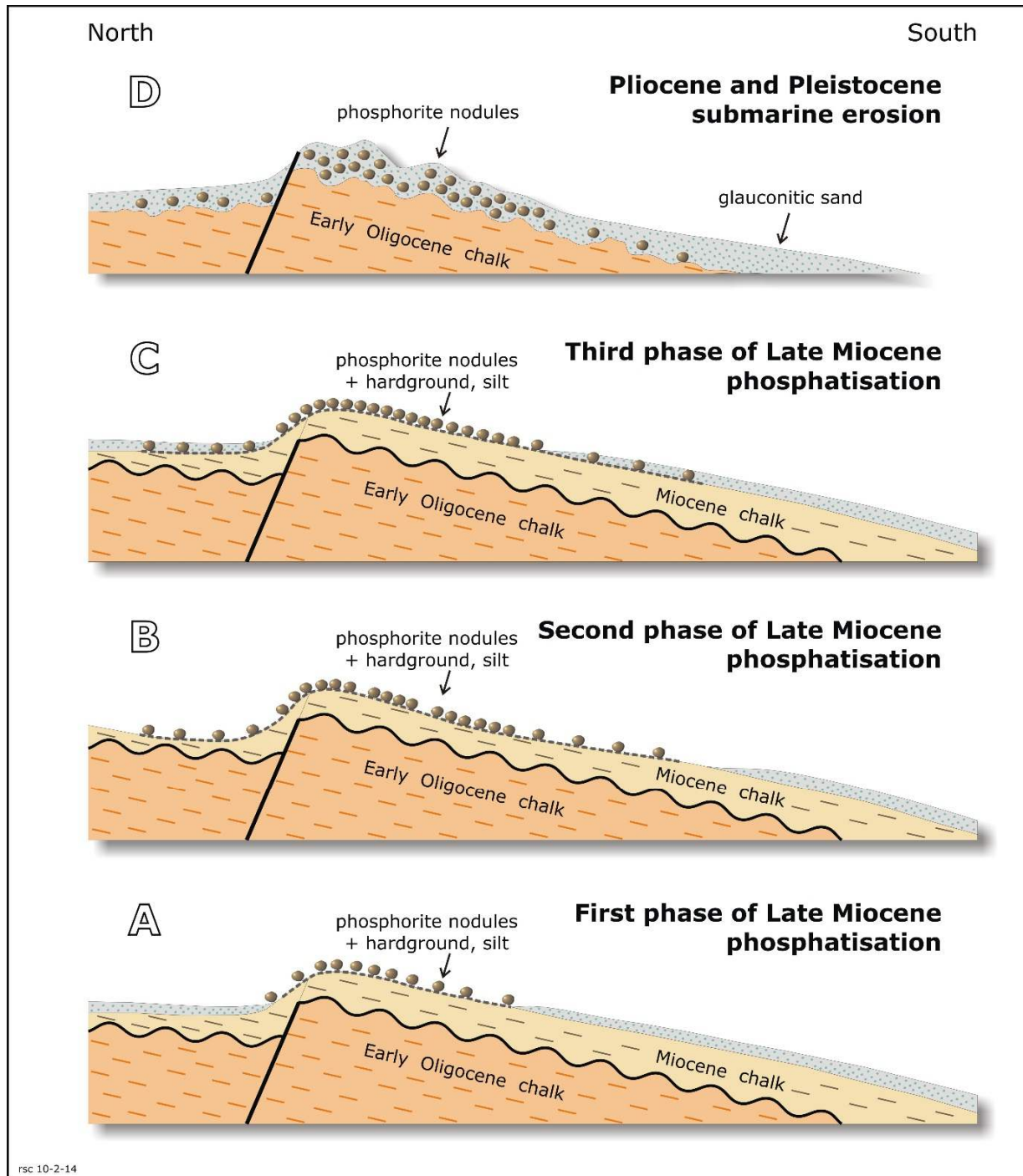


Figure 7-2: Schematic illustration of morphological controls on phosphatisation with repeated cycles of partial burial, phosphatisation, erosion, and hard-ground formation (adapted from Kudrass & von Rad, 1984).

7.2 Local & Property Geology

Local reactivation of faults during the Eocene (55–33 Ma) resulted in the development of depositional centres and regional subsidence on the flanks of the Chatham Rise. Pelagic nano-ooze sedimentation continued until a period of erosion and

phosphatisation in the Late Miocene that coincides with regional cooling of the oceans, the evolution of upwelling currents, and an increase in radiolarians (Kudrass & von Rad, 1984).

Geochemical results indicate that the sizes and shapes of phosphorite nodules on the Chatham Rise are likely related to the original disintegration of Miocene chalks prior to phosphatisation, as almost all of the geochemical parameters of the nodules are size dependent (Kudrass & Cullen, 1982). Evidence presented by Kudrass and von Rad (1984) suggests the surface chalk pebbles were phosphatised during several phases of submarine erosion and hard-ground formation during the Miocene (Figure 7-2). While Frontin-Rollet et al. (2022) noted that nodules can form around shells, foraminifera and other fossils, such as sharks teeth. Small elevations on the seafloor in the central part of the rise that formed in response to Late Oligocene faulting may have provided sufficient relief for erosion and phosphorite formation (Kudrass & von Rad, 1984). In deeper areas, phosphatisation was limited due to slower rates of erosion and limited exposure of the nodules. During the cyclical development of new phosphorite nodules, pebbles were phosphatised up to size-dependent saturation levels of 17–21% P_2O_5 . Less-phosphatised nodules were typically eroded during subsequent phases of erosion. These processes resulted in fairly uniform P_2O_5 concentrations in the nodules, irrespective of their provenance from phosphorite-rich or phosphorite-poor areas (Kudrass & von Rad, 1984).

Studies by Zachos et al. (2001) and Haywood et al. (2004) on the palaeoceanographic history of the Pacific Ocean and areas east of New Zealand have further detailed ocean current models and sea chemistry changes since the Miocene. Some of these findings have implications for the development and timing of phosphorite nodules on the Chatham Rise, suggesting later phases of phosphatisation and phosphorite deposits forming over shorter timespans.

The phosphorite deposit occurs as a thin layer of phosphorite-bearing glauconitic sand with an average thickness of 0.2 m, and locally >0.5 m (Figure 7-3). The sand layer consists of mainly silt and sand-sized sediments, with phosphatised chalk pebbles measuring up to 15 cm in diameter. Nodule layers were initially stratified, representing periods of erosion and phosphatisation; however, post-depositional modifications have resulted in these layers becoming disrupted. The underlying chalk layer occurs as a white ooze at the base of the deposit. The upper 20–30 cm of this zone can be mixed due to bioturbation and includes burrows filled with the overlying sand. The ooze also contains weathered chalk, an important constituent for phosphorite nodule formation. At depth, the ooze grades into an indurated chalk layer.

7.2.1 Seismic Facies

Mapping of the seafloor sediment units was undertaken on the *RV Sonne* using a Hunttec high-resolution seismic system. The seismic facies are based on seabed morphology, amplitude of bottom reflection, distinct sub-bottom reflectors, and seismic stratigraphy of the sub-bottom geology (Falconer et al., 1984). There is a wide variety of seismic character, even over short (100 m) distances, with boundaries having both abrupt and subtle changes. The boundaries of the ten mapped facies are illustrated in Figure 7-4. Minor modifications were made to the boundaries by Kenex (2014), based on structural analysis and updated bathymetric data.

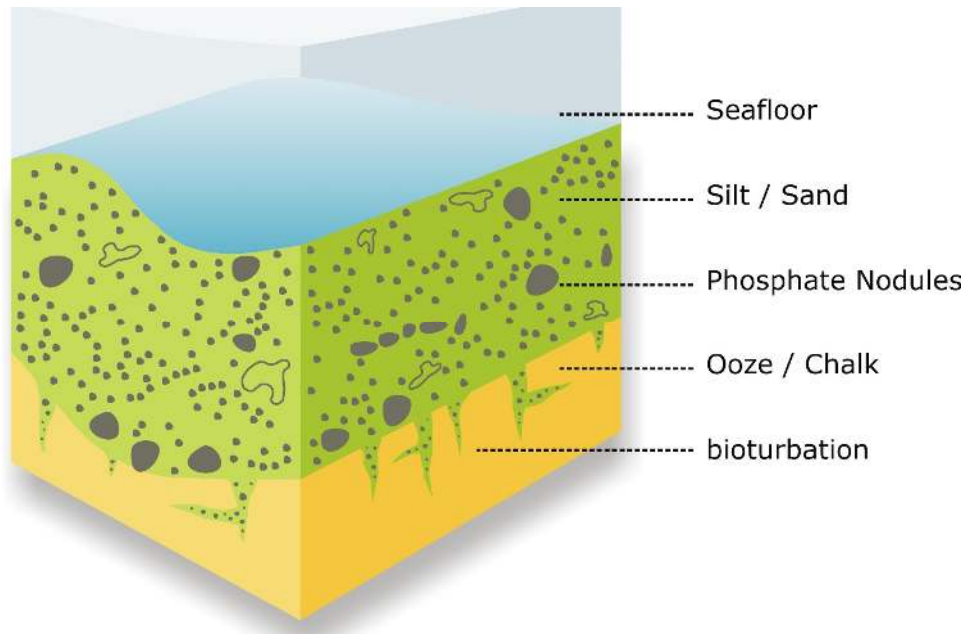


Figure 7-3: Schematic cross-section of phosphorite-bearing sand zone (adapted from CRP, 2012).

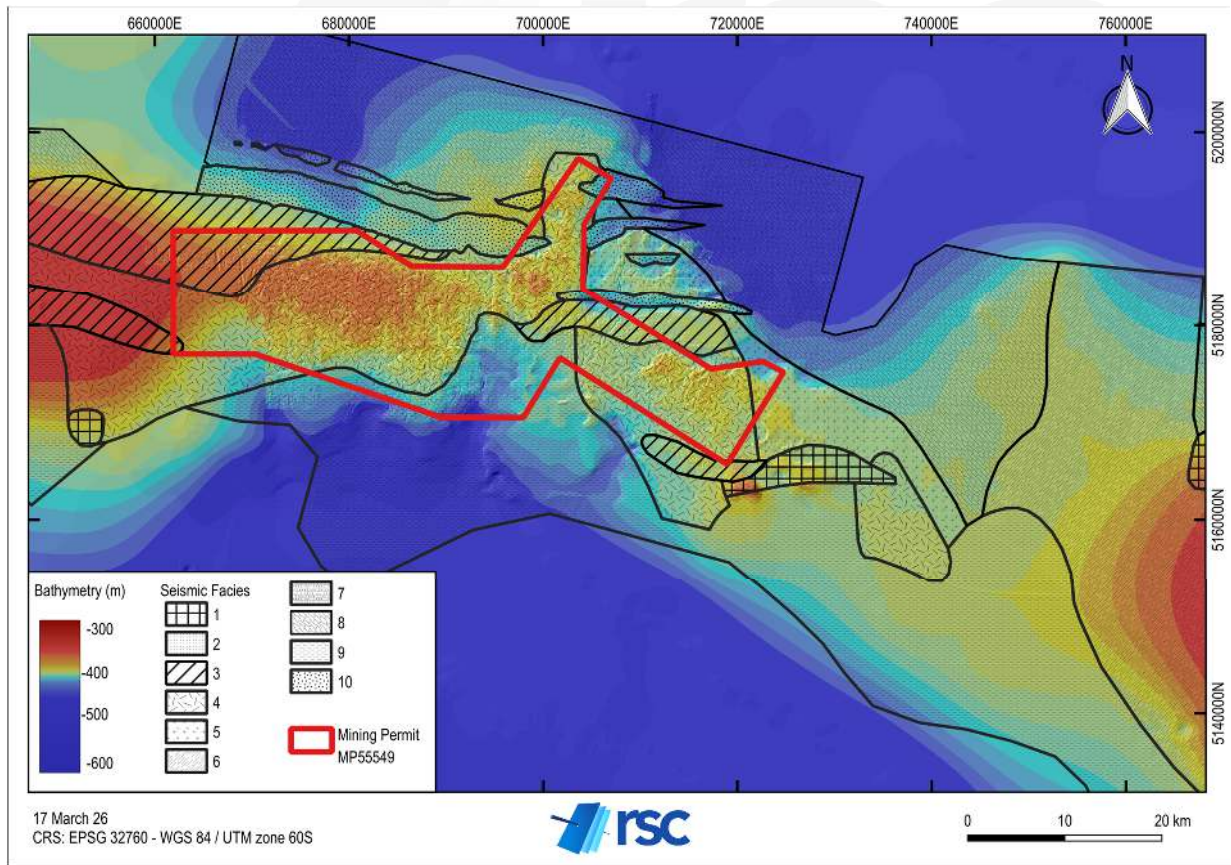


Figure 7-4: Seismic facies map (updated from Falconer et al., 1984).

Based on the seismic work, Falconer et al. (1984) suggested that the distribution of phosphorite was not directly related to structure or the thickness of major sedimentary units. However, the authors made correlations between the seismic facies and increased concentrations of phosphorite. For example, in the central part of the survey area, the highest phosphorite grade occurs in the Early–Middle Oligocene Unit 4, which overlies Unit 3. Prospectivity modelling by Kenex (2014) also indicated the most prospective targets with the highest relative nodule abundance occur in areas of Oligocene and Miocene chalk in the central saddle region, near local topographic highs and faults. The largest and highest-ranked deposits occur mainly within seismic facies 3, 4, 5, and 9.

7.2.2 Post-Depositional Modifications

Glacio-tectonic processes have had a significant influence on the morphology of the phosphorite resource and Chatham Rise. Kudrass and Cullen (1982) first suggested the idea that gouging icebergs have a significant influence on the redistribution of the phosphorite and may partially explain the high variability in short-range grade. Furrows caused by the movement of grounded icebergs and pits produced by rotating icebergs are the most significant structural elements, and range in scale from a few metres to hundreds of metres. These impacts shaped the morphology of the Project area by excavating the chalk to a depth of 15 m along furrows and in the pits. The excavated chalk, together with the top layer of phosphorite sand, was displaced along the rims of the furrows and pits (Kudrass & Cullen, 1982). This process was probably repeated during each of the five main Pleistocene glacial periods. In the long interglacial periods, the sea level was lower, and the seafloor was smoothed by winnowing of the silt and sand, filling of the depressions, bioturbation and dissolution of the exposed chalk. Some previously buried phosphorite nodules were thus exposed and available for further phosphorite enrichment at the seafloor-water interface (Kudrass & Cullen, 1982).

Furrows are the most prominent seafloor features in the multibeam swath bathymetry images from the Project area and are visible at all scales of observation, with widths that range from 1–240 m. The largest furrow has excavated 30 m of chalk. Most of the larger furrows can be traced over a few kilometres, with the longest extending for >25 km (Figure 7-5). Large furrows predominantly trend northwest and northeast, with the orientations of smaller furrows being highly variable. Larger furrows typically have elevated rims measuring a few metres, where chalk is either exposed or covered by a thin layer of glauconite-phosphorite sand. Many furrows are interpreted to have been partly filled by silt and sand. Preferential filling from one side, indicative of a preferred direction of sediment transport, was not observed (Kudrass & Cullen, 1982).

Pit marks with diameters of a few metres are visible on ROV multibeam data; the larger ones visible on regional bathymetric maps have a maximum diameter of 700 m. Smaller pits are typically round (up 50-m diameter), and larger pits (up 300-m diameter) are either triangular or lenticular in shape with smooth, well-defined rims, or sub-rounded with highly irregular rims. Medium-sized pits have depths of ~10 m. Pits occur in almost all water depths in the Project area. While Kudrass and Cullen (1982) suggest the pits were made by grounded icebergs, Davy et al. (2010) suggest that the pock marks on the Chatham Rise were formed as a result of gas release from dissociating hydrates during glacial-interglacial cycles. These pock marks, observed in water depths of 500–700 m, may have formed during glacial periods in response to the movement of the seafloor out of the gas hydrate stability zone with falling sea levels and/or warming of bottom water.

In the modern environment, the phosphorite layer continues to be modified through bioturbation and reworking, and locally by slow deposition (Kudrass & von Rad, 1984). Bioturbation holes and furrows can be up to 20 cm deep and 70 cm wide.

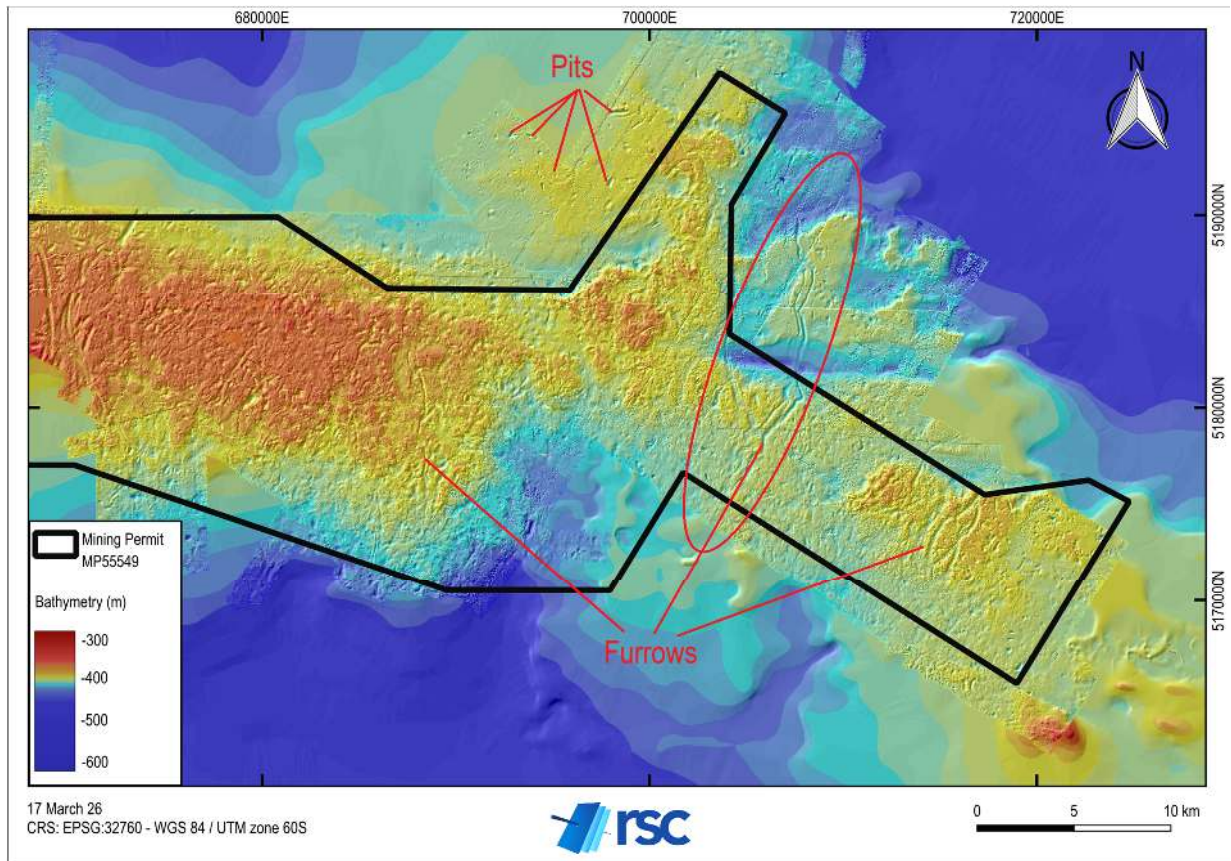


Figure 7-5: Interpreted iceberg furrows observed in bathymetry imagery.

7.3 Mineralisation

Phosphorite nodules in the Project area are loosely distributed within a layer of Neogene glauconitic sand that typically measures ~20 cm thick, but locally it is >1 m. The sand is a pelagic lag deposit that comprises 20–40% silt and 30–60% fine-grained to very fine-grained sand. The concentration of phosphorite nodules varies both vertically and laterally.

Kudrass and von Rad (1984) suggested two possible modes of phosphatisation resulting from diagenetic processes.

1. The replacement of CaO in pore water of organic-rich anoxic sediments, with phosphorus released through bacterial activity (Figure 7-6). This process typically occurs on the upper continental slopes and outer shelf areas with upwelling nutrient-rich water.
2. The replacement of CaO by direct uptake of phosphorus dissolved in seawater (Figure 7-6) The absorption of phosphorite by the organic coating of the chalk may enhance this process, which is limited to areas with phosphorus-rich seawater.

Frontin-Rollet et al. (2022) suggested that the typical continental margin upwelling environment is most favourable for phosphatisation, with periods of strong current winnowing and low organic matter deposition for phosphogenesis within the sediment profile (Figure 7-7).

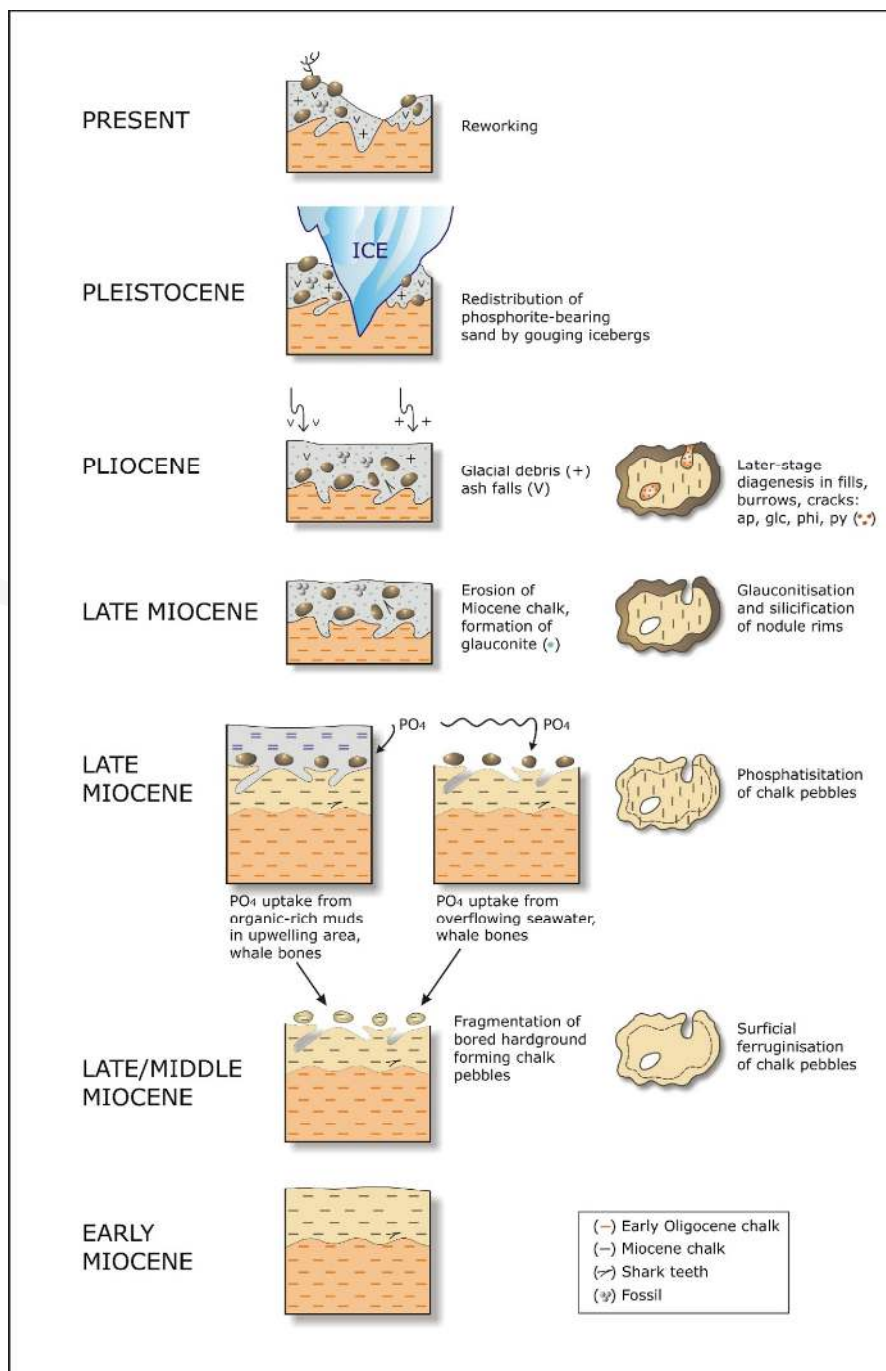


Figure 7-6: Evolution of the Chatham Rise phosphorite deposit and associated sediment, with alternative models for the phosphatisation process (adapted from Kudrass & von Rad, 1984).

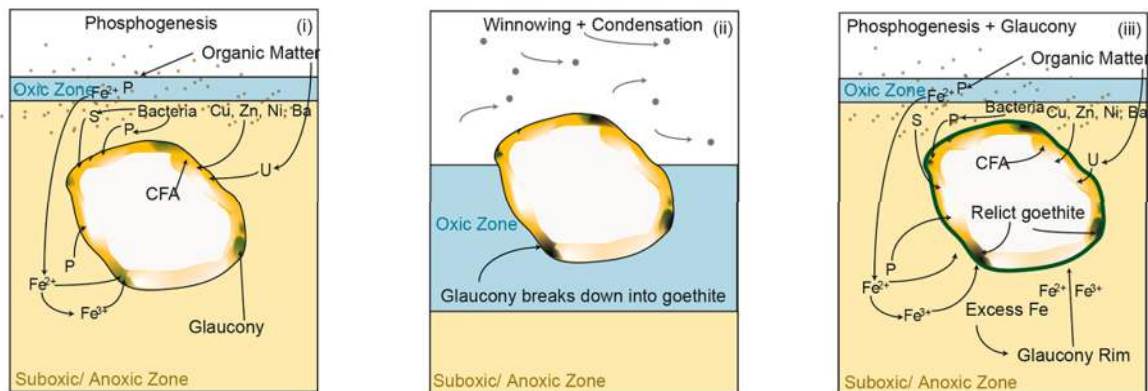


Figure 7-7: Formation of a Chatham Rise phosphorite nodule. Figure sourced from Frontin-Rollet et al. (2022), with redox horizons and chemical reactions adapted from Froelich et al. (1988) and Jarvis et al. (1994).

Climate optima for phosphatisation can be created by the alternation of conditions encouraging high primary productivity at the ocean surface and current winnowing events (such as ice sheet growth or bottom-current strengthening; Hein et al., 1993; Benninger & Hein, 2000). The differences in redox states of the depositional environment control the mineralogical and compositional variations (Frontin-Rollet et al., 2022).

Frontin-Rollet et al. (2022) outlined that trace-element concentrations (such as cadmium, Cd) are linked to the depositional environment, formation processes, and associated mineral phases (von Rad & Rösch 1984; Froelich et al., 1988; Glenn & Arthur, 1988; O'Brien et al., 1990; Mar & Okazaki, 2012). Continental margin phosphorites favour the breakdown of glaucony into goethite (Frontin-Rollet et al., 2022). Negative cerium (Ce) anomalies may represent oxic seawater and/or sediment pore water during phosphogenesis (Jarvis et al., 1994; Shields & Stille, 2001; Pattan et al., 2005). The suboxic to anoxic environment on the Chatham Rise continental margin during the Miocene was sufficient to enrich and concentrate U, but not Cd (Frontin-Rollet et al., 2022). Uranium enrichment by reduction to U^{4+} by adsorption into organic matter (Bone et al., 2017) and subsequent release by bacterial breakdown to insoluble uranite occurs during anoxic conditions (Klinkhammer & Palmer, 1991). Continental margin phosphorites (such as those on the Chatham Rise) are also enriched in vanadium (Frontin-Rollet et al., 2022).

Phosphatisation was followed by glauconitisation and silicification of the nodules. Sand and mineral-filled fractures and borings on the surface of nodules were subsequently cemented by later-stage diagenetic processes (Figure 7-6). The modern composition of the phosphorite nodules developed during the late Miocene due to diagenetic replacement of the chalk pebbles (Figure 7-6) (Kudrass & von Rad, 1984). Apatite-based cement replaced pre-existing glauconite, suggesting that the main Late Miocene phosphatisation event was followed by minor authigenic phosphatisation, which mainly cemented fractures and bore holes (Kudrass & von Rad, 1984).

Later-stage mineral input during phosphatisation was derived from volcanic ash, which added rhyolite glass and pumice to the phosphorite-glauconite sand. The source of this material is thought to be eruptions at North Island volcanic centres over the last 40 kyr (Kudrass & von Rad, 1984). Subsequent modification by icebergs (see Section 7.2.2) resulted in the reworking of phosphorite material and a highly irregular distribution. It is possible that the gouging icebergs removed the phosphorite in the furrows and created higher-grade phosphorite accumulations along parallel ridges beside the furrows (Figure 7-6).

8. Deposit Types

Phosphorites are classified as sediments that include significant portions of authigenic and biogenic phosphorite minerals, mainly the calcium-fluorapatite mineral francolite $((Ca, Mg, Sr, Na)_{10}(PO_4CO_3)F_{2-3})$. A lower threshold of 18% P_2O_5 is commonly used for the definition of phosphorite (Paytan & McLaughlin, 2007). Phosphorite deposits are known in ocean basins around the globe and have formed during numerous time intervals throughout geological history as the result of intensive phosphorus accumulation and subsequent authigenic francolite formation. Many phosphorite deposits were formed during the Miocene ~23–5 Ma.

Input of phosphorus into the oceans is by fluvial transport of organic and inorganic phosphorus compounds (usually carried by Fe oxyhydroxide) from the weathering of sedimentary and igneous rocks. Phosphorus is eventually transferred into the deep ocean where most of it is reintroduced into the photic zone by upwelling. A small fraction (~5%) is removed from the water column predominantly by primary production as organic phosphate, and partially as inorganic phosphate through adsorption to Fe and Mg oxyhydroxides, or authigenic phosphate mineralisation (Figure 8-1, Paytan & McLaughlin, 2007).

Diverse theories regarding the genesis of phosphorites have been published (e.g. Bentor, 1980; Cook, 1984). In these studies, the association of extensive phosphorite deposits with the fringes of oxygen minimum zones and reducing sediments has led to the conclusion that the dissolution of phosphorus is initiated by the oxidation of organic matter during sulphate reduction (Berner, 1980; Colman & Holland, 2000). When saturation of dissolved phosphorus in the interstitial water is reached, phosphorite can precipitate in an inorganic form through physical-biochemical processes. Modern marine phosphorite deposits are restricted to the continental margins off South Africa, the Gulf of California, South America, Eastern Australia, and New Zealand (Burnett & Riggs, 1990; Birch et al., 1983; Kudrass et al., 2017). A number of these regions (Chile-Peru, California, offshore South Africa and New Zealand) are almost exclusively associated with the upwelling of cold nutrient-rich waters onto continental shelves, organic-rich diatomaceous sediments, low net sediment-accumulation rates and low oxygen availability at the sediment-water interface. Upwelling provides a continual supply of nutrients to the surface waters, and results in high primary productivities (Burnett & Riggs, 1980).

Phosphorite forms diagenetically within anoxic sediments due to the microbial decay of organic matter, which enriches interstitial water in dissolved inorganic phosphorus (Berner, 1980). These areas are also characterised by current-dominated sedimentary regimes that are responsible for cycles of sediment reworking and subsequent phosphorite lithification (Burnett & Riggs, 1990). However, phosphorite deposits in some of these regions, in particular western South Africa and Eastern Australia, have demonstrated that decaying organic matter does not seem to supply the majority of dissolved inorganic phosphorus that sustains francolite growth; other sedimentary processes, such as Fe-redox cycling or fish-bone dissolution, might contribute much of the dissolved inorganic phosphorus required for the formation of phosphorite (e.g. Glenn et al., 1994). On the Chatham Rise, historical sampling has documented phosphorite nodules occurring over several thousand square kilometres of seafloor. The nodules typically occur in the upper <1 m of unconsolidated seafloor sediment, in a concentrated phosphorite-bearing horizon averaging ~0.3 m thick. Nodules are <15 cm in diameter. Rarely, larger fragments of phosphatised chalk have been recovered (e.g. Cullen, 1987; Kudrass, et al.; 2017).

The shallow depth of nodules beneath the seafloor, unconsolidated nature of the deposits and range in the diameter and concentration of phosphorite nodules means they are most suited to large volume, shallow seafloor penetration sampling techniques (see Section 26; Sterk & Stein, 2015).

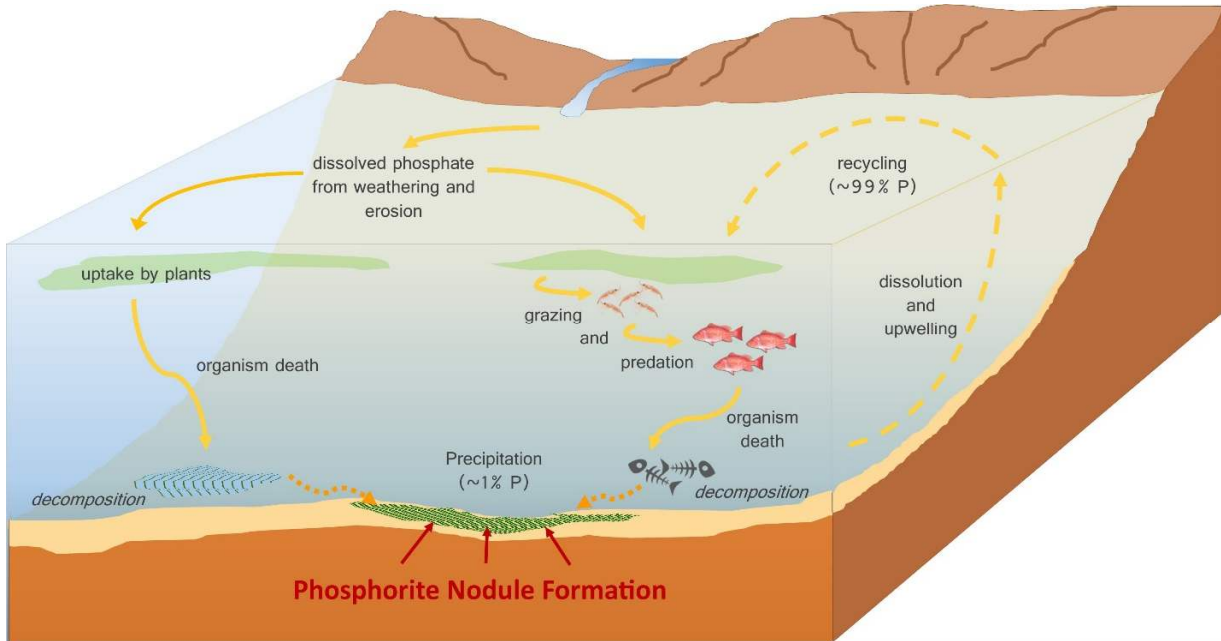


Figure 8-1: Phosphate cycle (adapted from Paytan & McLaughlin, 2007).

9. Exploration

CRP conducted two exploration programmes from 2010–2012 with a total of six cruises. The purpose of the cruises was to collect a variety of data, including samples for phosphorite abundance estimation, geochemical analysis, geotechnical samples, geophysical surveys and environmental baseline data.

9.1 *MV Tranquil Image* (2011)

The two campaigns of seafloor sampling that were carried out by CRP in early 2011 were done under contract by IXSurvey Australia Pty Ltd (IXSurvey 2010, 2011). The vessel used for both cruises was the *MV Tranquil Image* owned and operated by Western Work Boats Ltd of Tauranga, New Zealand.

9.1.1 Sample Locations

During the two cruises, sample locations were determined by GPS. The approximate location was established by the navigation equipment installed on the vessel and the actual sample location was recorded using a hand-held GPS at the time the sample was taken on board. GPS is a satellite-based navigation system with precision of 5 m. Penetration depths were not recorded for the *MV Tranquil Image* grab samples, so the depth of sampled sediment is unknown. However, the dimensions of the grab sampler mean maximum sample depth is ~30 cm.

9.1.2 Sampling Method

Sediment samples were collected at predetermined locations. The samples were collected using a Van Veen grab sampler provided by NIWA. The Van Veen grab sampler used for this programme was small and had a surface area of 0.25 m² (Figure 9-1). The range of total sample weights varied from 2–40 kg. Due to the Van Veen grab sampler's limited weight and non-powered jaws, it had a maximum sample depth of 30 cm. As with the *RV Valdivia*, the grab sampler also encountered problems with stones and nodules being caught in the jaws and allowing sample loss. Sample volumes have not been evaluated by the QP, as penetration depths for the samples were not recorded. The shallow depth of the sample penetration and lack of chalk or ooze in samples indicate that the Van Veen grab sampler typically failed to test the full thickness of the glauconitic sand layer.

Sampling activity undertaken during the *MV Tranquil Image* cruises is summarised in Table 9-1.

Table 9-1: *MV Tranquil Image* cruise activity.

Cruise No.	Date	Activity	Amount
1	May 2011	Van Veen sampling	23
		Deployment of current meter mooring	1
		CTD casts	4
2	May 2011	Van Veen sampling	32
		Deployment of turbidity monitors	2

Note: CTD - conductivity, temperature, and depth

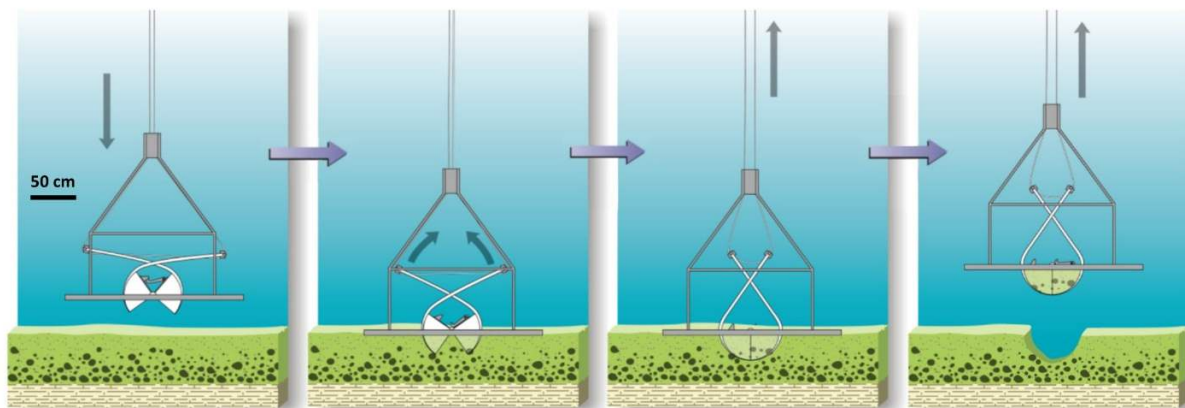


Figure 9-1: Sampling method for NIWA's Van Veen grab sampler.

9.1.3 Logging

For each grab sample, the grab number, date, time (GMT), latitude, longitude, and water depth were recorded along with a geological description of the grab sampler contents. A photograph of each sample was also taken. Data were entered directly into a spreadsheet on board the vessel.

9.1.4 Results

The QP reviewed laboratory test results for the 45 successful *MV Tranquil Image* grab samples that record sample wet weight and the dry weight per cent of the >2 mm fraction of the sediment. However, the sample weight was not recorded for four of these samples. There is insufficient information to reliably calculate the phosphorite grade of the samples, and the QP has several concerns with the sampling process used on the *MV Tranquil Image* (Section 11.5).

Phosphorite nodule abundance was estimated from the available data by assuming that the >2 mm fraction of sieved sediment was 100% phosphorite and multiplying the dry weight per cent of this fraction by the wet bulk sample weight to estimate the contained kilograms of phosphorite in the sample. The weight was divided by the sample area of the grab sampler (0.25 m, based on information provided by NIWA) to calculate phosphorite nodule abundance for the samples. This estimated nodule abundance ranges up to 45.0 Ph kg/m² and averages 9.6 Ph kg/m². The QP is of the opinion that the assumption that the entirety of the >2 mm fraction of the sampled sediment comprises phosphorite is not valid (see Section 11.5), and that the use of a weight per cent determined from dry material proportioned against a wet sample weight will lead to an overestimation of grade, as moisture content is not taken into account. The practice of removing subsamples for various onshore tests resulted in the original sample being reduced in size in a manner that is likely to add further error and possibly introduce bias to the calculated phosphorite grade.

The QP estimated phosphorite grade for the samples by multiplying the dry phosphorite weight percentages (assumed to be equivalent to the >2 mm dry weight %) of the samples by the average dry density of phosphate nodules (2.65 g/cm³; see Section 11.2). This yielded unreasonably high grades up to 2,246.8 Ph kg/m³ and averaging 677.4 Ph kg/m³ (Figure 9-2).

The QP considers that data for the *MV Tranquil Image* samples are insufficient to reliably calculate phosphorite grade; none of the samples were therefore included in the resource model (see Section 11.5 and Section 12).

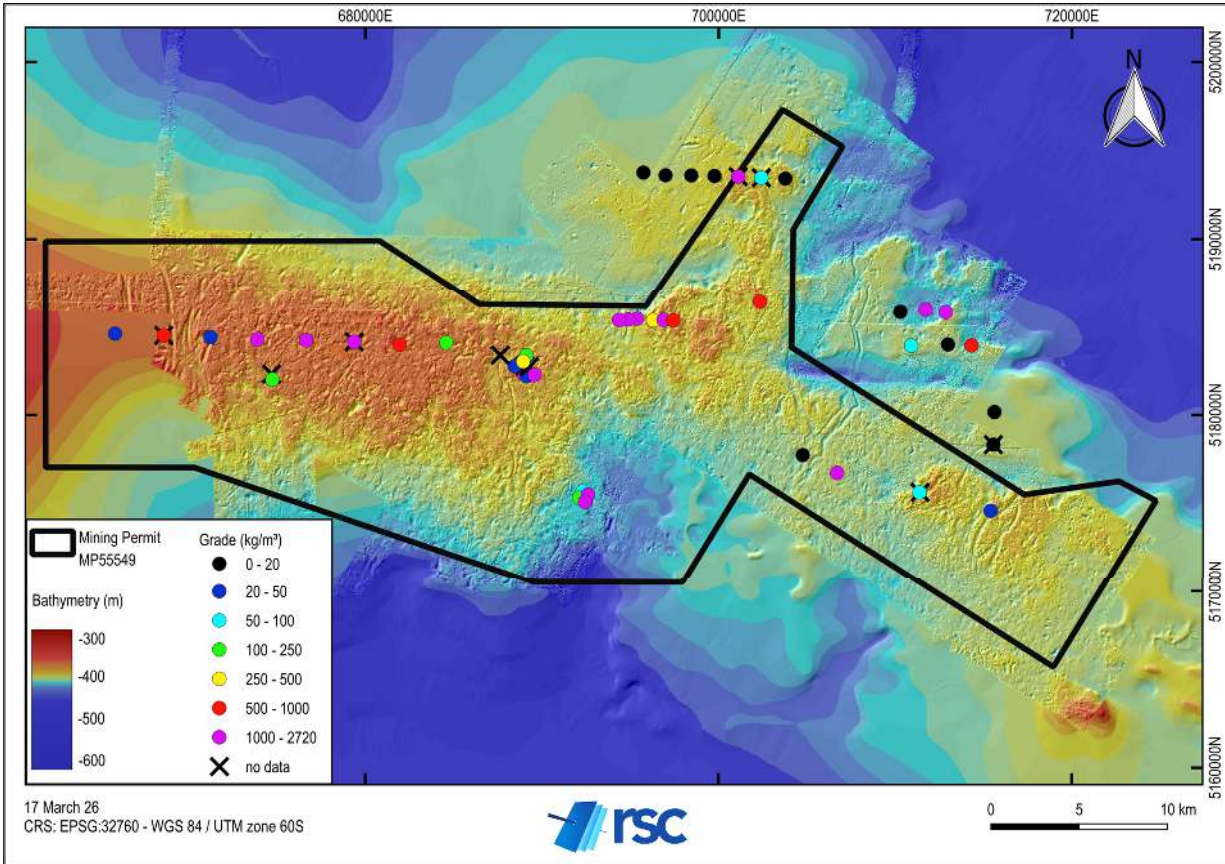


Figure 9-2: *MV Tranquil Image* sample locations and updated phosphorite grade.

9.2 *RV Dorado Discovery* (2011–2012)

CRP chartered the *RV Dorado Discovery*, a 100-m-long, fully equipped research vessel, from Odyssey Marine Exploration for work on four consecutive cruises.

Cruise 1: In December 2011, the *RV Dorado Discovery* completed a 12-day voyage mapping the seafloor and collected 715 km² of multi-beam swath bathymetry data, 199 km² of side-scan sonar data, and 263 km of sub-bottom seismic reflection and magnetic data. The main objectives of the cruise were to improve knowledge of the distribution of phosphorite on the Chatham Rise, to provide information that will support the development of suitable mining technology and strategy, and to establish target areas for a follow-up geotechnical cruise. Four areas in the western part of MPL 50270 were identified as primary survey targets, with another four areas identified as possible targets. The two oceanographic moorings previously deployed by IXSurvey were also retrieved during this cruise, and the current and turbidity data were downloaded for processing and analysis (Wood, 2012).

Cruise 2: From 31 January to 10 February 2012, the *RV Dorado Discovery* was used to collect additional multi-beam swath bathymetry and to test a large clamshell grab sampler for sediment sampling. The grab sampler weighed ~2 t and had a cross-sectional sampling area of 1.42 m (width) × 2.03 m (length). Remotely operated underwater vehicle (ROV) dives were undertaken to view the seabed before and after grab sampling to assess the size and shape of the 'scar' left by the grab

sampler. Although it was planned as a test run, all 50 of the potential sites were sampled, recovering more than 32 t of sediment. Sample sizes ranged from ~300 kg to almost 2,000 kg. A total of 43 push cores (30 cm long) were taken from suitable grab samples. In addition to the cores, 172 subsamples totalling more than 500 kg were taken from the grab samplers, and the remaining material was collected in bulka bags (Nielsen & Berthelsen, 2012).

Cruise 3: During March 2012, the bottom-dwelling pelagic and benthic ecology of the Chatham Rise was investigated, with a view to examining the potential impact of mining on seabed ecology. A team of ecologists and geologists from NIWA, GNS Science, Golder Associates (Golder), and Kenex conducted the data collection and sampling, using an ROV to conduct photographic traverses to document the seafloor (totalling 17,003 still photographs and 143 hours of video footage) and a 20 cm × 30 cm × 45 cm box corer to collect 130 sediment samples. Three attempts to collect sediment using a small Van Veen grab sampler were unsuccessful, and one grab sample was collected using the large clamshell grab sampler previously used during Cruise 2. Additional multi-beam swath bathymetry data were also collected during the cruise (Nielsen et al., 2012a).

Cruise 4: During April 2012, the geotechnical properties of the seabed were determined by performing in-situ tests and collecting sediment samples with the aim of optimising the design of the dredging equipment proposed by Boskalis for mining the Chatham Rise phosphorite deposits. Sediment sampling was conducted using a 400-kg vibracorer equipped with interchangeable 3-m barrels (80 mm and 150 mm diameters), and a 1,200-kg box corer measuring 50 cm × 50 cm × 50 cm with dual closing shovels that could have an additional 600 kg of weight added. Cone penetration tests (CPTs) were conducted using a 2-cm² cone and 1,000-kg thrust capacity capped at 25 MPa, and ROV jetting tests were conducted to establish the jetting strengths needed to mobilise the target sediment. When weather did not permit safe operations on deck, multi-beam swath bathymetry data were collected to expand the existing mapped area (Nielsen et al., 2012b).

Sampling activity undertaken during the *RV Dorado Discovery* cruises is summarised in Table 9-2.

9.2.1 Sample Locations

Sample locations were determined using a Hemisphere GPS receiver, which accessed Fugro's Veripos service for position augmentation, recording geographical coordinates and height on the WGS84 datum. Although Universal Transverse Mercator (UTM) coordinates were required, for ease of post-processing, all positioning data were recorded in latitude and longitude coordinates (Wood, 2012).

9.2.2 Sampling Method

Seafloor sampling was conducted using the large clamshell grab sampler and box corer. Despite its size and weight, the large clamshell grab sampler had poor penetration power, especially in nodule-rich sediment. It was lowered to the seafloor and closed by recalling the cable, causing the hinge of the bucket to rise and the jaws to close under their own weight (Figure 9-3).

Table 9-2: *RV Dorado Discovery* cruise activity.

Cruise No	Date	Activity	Amount
1	Dec 2011	Multi-beam swath bathymetry	715 line km
		Magnetometer	217 line km
		Sub-bottom profiler	271 line km
		Side-scan sonar	197 line km
2	Jan to Feb 2012	ROV dives and seabed descriptions	3
		Multi-beam bathymetry	
		Grab samples	50 attempts
		Push cores	43
		Subsamples	172
		Vane shear tests	29
3	Mar 2012	ROV dives	14
		ROV lines	42
		Multi-beam bathymetry	
		Box cores	130 attempts
		Van Veen grab samples	3 attempts
		Grab samples	1
		Push cores	81
4	Apr 2012	ROV jetting tests	3
		Multi-beam bathymetry	426 km ²
		Vibracores	21 attempts
		Box cores	8 attempts
		CPT tests	134
		Bulk density determination	10
		Vane shear tests	24

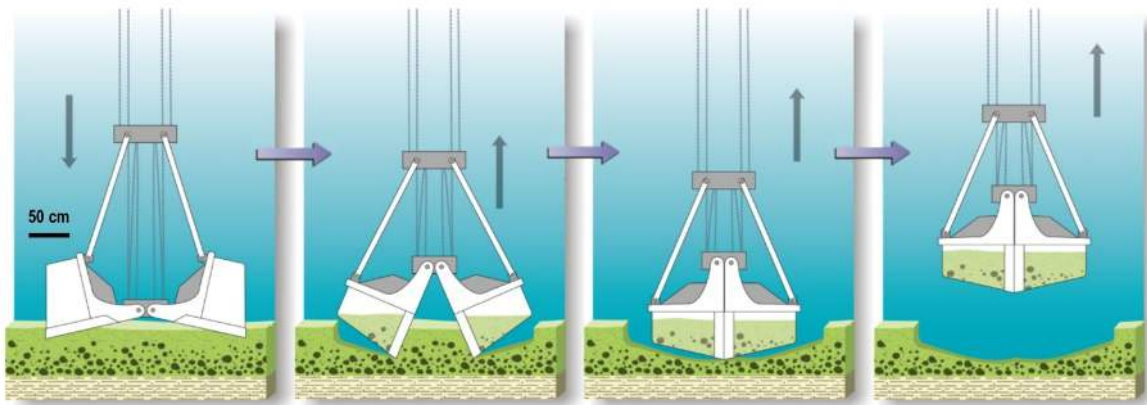


Figure 9-3: *RV Dorado Discovery* clamshell grab sampling process.

The grab sampler had previously been used as a junk yard excavator and was not specifically designed for undersea sampling. In addition to poor penetration power relative to its size, the main drawback of the clamshell grab sampler as a sampling tool is that it was not enclosed, resulting in washing of the contained sediment when the grab sampler was retrieved, particularly at the sea surface where it was exposed to wave action (Figure 9-4 and Figure 9-5). Most samples

were noted as having undergone some degree of washing, and this was more pronounced when the grab sampler contained smaller volume samples (Simon Nielsen, pers. comm.). The amount of material lost to washing is unknown. In addition, the geometry of the grab sampler (2.03 m × 1.42 m when open and ~1.4 m × 1.42 m when closed) indicates that the sampled sediment in the clamshell grab sampler undergoes compression as the bucket closes (in a similar way to the sediment in the *RV Sonne* grab sampler, as discussed in Section 6.2.6), which has implications for determination of the true sample depth of the grab samples.

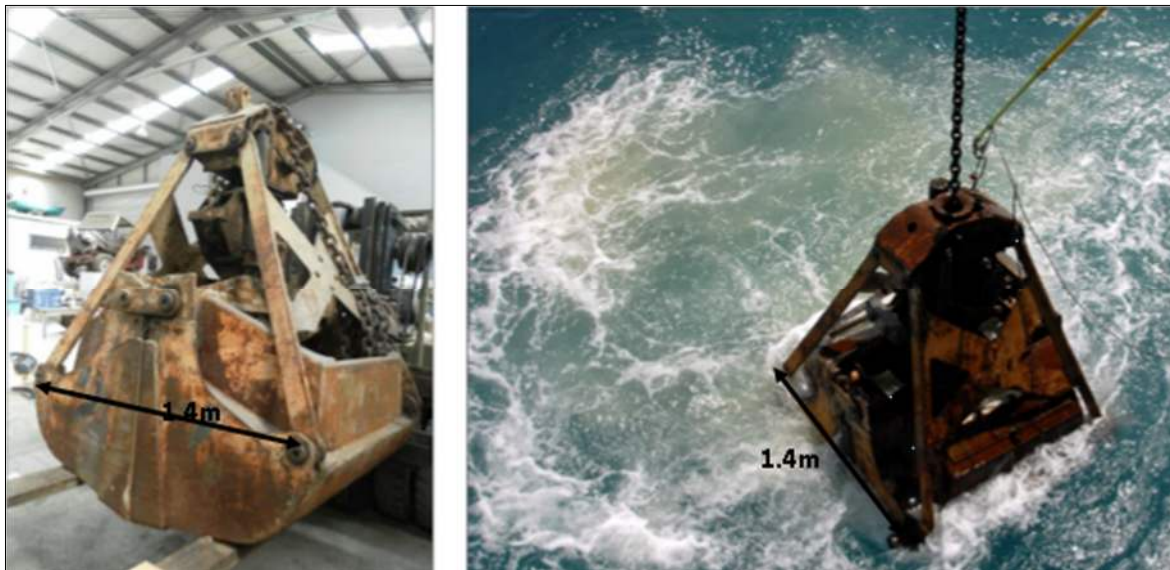


Figure 9-4: Clamshell grab sampler used on the *RV Dorado Discovery*. As it was not enclosed (left), sediment was washed from the bucket during retrieval, as indicated by the discolouration of the water surrounding the grab sampler (right).

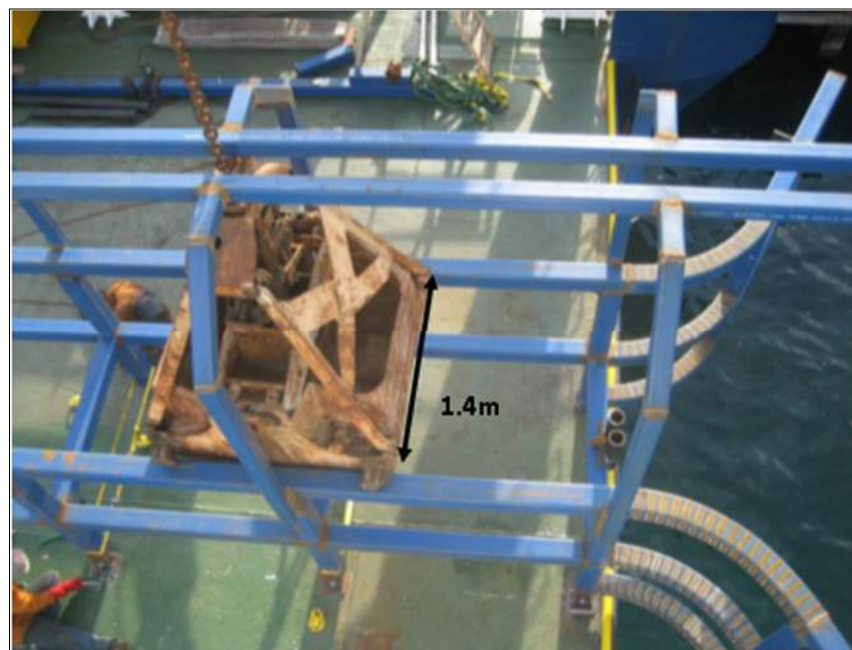


Figure 9-5: *RV Dorado Discovery* grab sampler retrieval.

In addition to the large grab samples, 138 box cores were attempted during Cruises 2 and 3 of the *RV Dorado Discovery*. The first 130 samples were attempted using a 20 cm × 30 cm × 45 cm box corer (Figure 9-6), and the remaining eight cores were collected using a 50 cm × 50 cm × 50 cm box corer with dual closing shuttles. A total of 119 bulk samples were collected using the box corers. Problems were encountered with the dual-shovel closing mechanism not operating correctly, and several attempts to adjust the apparatus were unsuccessful. Sampling with the box corer was discontinued during Cruise 4.

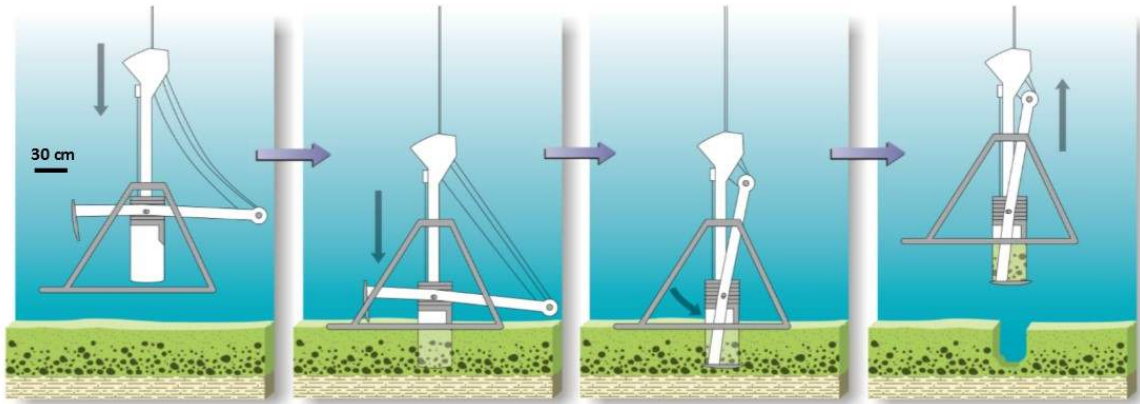


Figure 9-6: *RV Dorado Discovery* box core sampling.

During Cruise 4 of the *RV Dorado Discovery*, 14 vibracore samples (from 21 attempts) were collected using a 400 -kg, 3.5-m long vibracorer equipped with a 3-m long, 80-mm-diameter barrel. In addition, 134 CPTs were conducted using a Neptune 3000 Miniature Coiled Rod CPT system with 2-cm² rods and a 1,000-kg thrust capacity. For safety, the applied pressure was capped at 25 MPa.

9.2.3 Logging

Upon retrieval of the large clamshell grab sampler, the geologist on deck assessed the sample by viewing it through openings in the top of the closed grab sampler. For a full grab sample, the sample surface was easily reached but with limited overview of the surface. For a very small sample, the surface was not within safe reach, but was easily viewed through ports in the grab sampler. The surface composition and condition of the sample were described by the geologist, and biota and signs of disturbance were noted. The completeness of fill (penetration depth) of sediment in the grab sampler was estimated, and photographs were taken to visually record the sample surface.

The sample was emptied into a collection hopper, and a description of the bulk sediment was made; this emphasised sediment type and texture and abundance of black sand and nodules, and recorded any layering and difference in sediment types in heterogeneous samples. The presence/absence of glauconitic sand, phosphorite nodules, clays, and chalk was noted. The size and frequency of nodules were estimated, as well as overall sediment firmness. Infauna or other biota not

seen or unreachable from the top of the closed grab sampler were logged and sampled. Photographs were taken of the bulk sediment in the hopper.

Upon retrieval of the box core samples, the surface composition of the samples was described prior to the corer being opened and the thickness of sediment in the box estimated. Descriptions used standard sedimentary descriptors, with emphasis on the presence/absence of black sand and phosphorite nodules (including descriptions of their size and frequency). Visible biota was described and sampled if possible, and photographs were taken of the sediment surface.

After the core sample was dumped into a collection bucket, a bulk description was recorded, with emphasis on sediment type and texture, the abundance of black sand and nodules, and any layering or difference in sediment types that was apparent in the samples. Photographs were also taken of each bulk sample in the collection bucket.

9.2.4 Results

Grade estimation for the *RV Dorado Discovery* data was completed for the large clamshell grab sampler and box core data. Grades needed to be calculated differently for each dataset due to the differences in data collection and recorded parameters for the different sampling methods and analyses.

The QP notes that the grab sampler used for sampling was not fully enclosed, resulting in documented washing of the samples and sediment loss. This washing is likely to have preferentially removed fines from the grab samples, which would result in concentration of the coarser denser phosphorite in the samples. This effect may have been mitigated to some extent by the size of most of the grab samples in that the proportion of sediment loss through washing may be overall smaller, but without detailed observations/estimates of the degree of washing that has occurred for each sample, all samples must be treated as having been washed out. The QP notes that the quality of samples and sample data is significantly reduced by the unconstrained recovery losses associated with sampling using a non-enclosed grab sampler.

CRP initially calculated the nodule abundance for the grab sampler data by summing the weights of the >8 mm and 0.8–8 mm sieved sediment fractions and dividing these by the sample area of the open grab sampler (2.8 m²), yielding a range in nodule abundance up to 92.3 Ph kg/m² and averaging 22.8 Ph kg/m². The QP calculated grades for the *RV Dorado Discovery* grab samples using the available data, but notes that the calculation relies on a number of assumptions that introduce error into the calculations, meaning that the resulting sample grades are unreliable (see Section 11.5).

The detailed work conducted on the >8 mm sieved fractions of subsamples of the grab samples (Berthelsen et al., 2012; see Section 11.1.2) yields the total contained kilograms of phosphorite in that fraction, which can be expressed as a percentage of the bulk sieved sample weight. This is a necessary step to remove the error caused by calculating phosphorite content in kilograms from sieved samples that are only a subsample of the original bulk grab sediment sample; however, it relies on the assumption that the sieved samples were representative of the bulk grab sample.

Volume percentages of phosphorite were determined for the 0.8–8 mm fractions of 12 grab samples by Nielsen (2012). The weight per cent of phosphorite measured in the >8 mm sieved fractions was plotted against the volume per cent of phosphorite observed in the equivalent sample's 0.8–8 mm fractions (excluding outliers), and this relationship was used to

estimate the volume of phosphorite in the 0.8–8 mm fractions of samples for which that fraction had not been assessed (Figure 9-7).

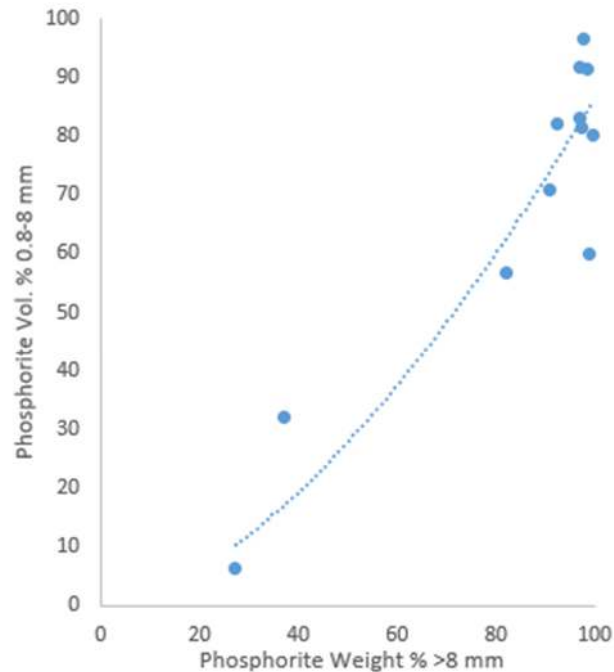


Figure 9-7: Relationship between sieved fractions of phosphorite contents in *RV Dorado Discovery* grab samples.

Assuming comparable density of all constituents in the >8 mm fractions, the phosphorite percentage for material >0.8 mm contained in the grab samples can be estimated. This percentage multiplied by the average density of wet phosphorite nodules (2.72 g/cm³) yields grades ranging up to 1,464 Ph kg/m³ and averaging 392.6 Ph kg/m³. The QP has concerns regarding this method of calculation, as it is based on a number of flawed assumptions that make the calculated grades unreliable (see Section 11.5).

True depths of the grab samples were calculated in an equivalent manner to the *RV Sonne* data. The clamshell grab sampler was modelled in 3D, and its cumulative volume calculated in 1-cm increments. These volumes were compared to the calculated volume of sediment sampled by the 2.03 m × 1.42 m open grab sampler in 1-cm increments to generate a conversion table of penetration depth to true depth for the clamshell grab sampler. This assumes that the observed penetration depth of sediment in the grab sampler reflects the penetration depth of sediment as it was originally sampled on the seafloor and has not been altered by washing. Since the grab sampler was not enclosed and all samples are therefore considered washed, it is likely that true sample thickness for the *RV Dorado Discovery* grab samples has been underestimated (Figure 9-8 and Figure 9-9).

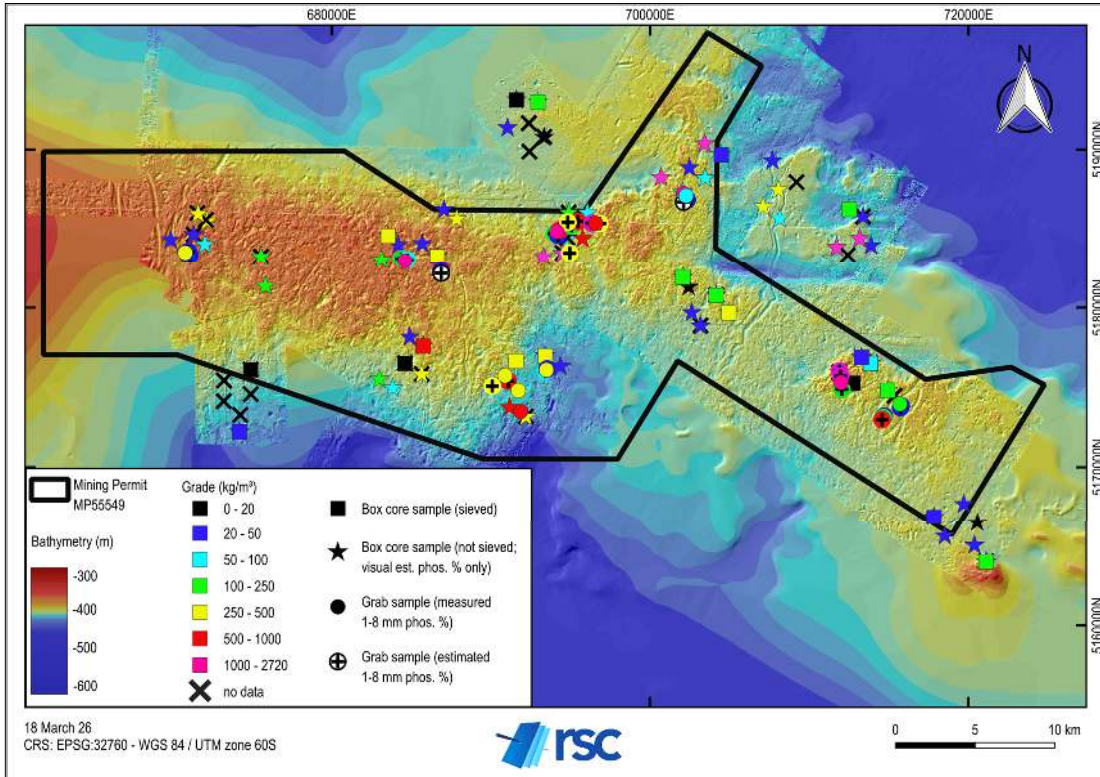


Figure 9-8: RV Dorado Discovery sampling methods, sample locations, and estimated grades.

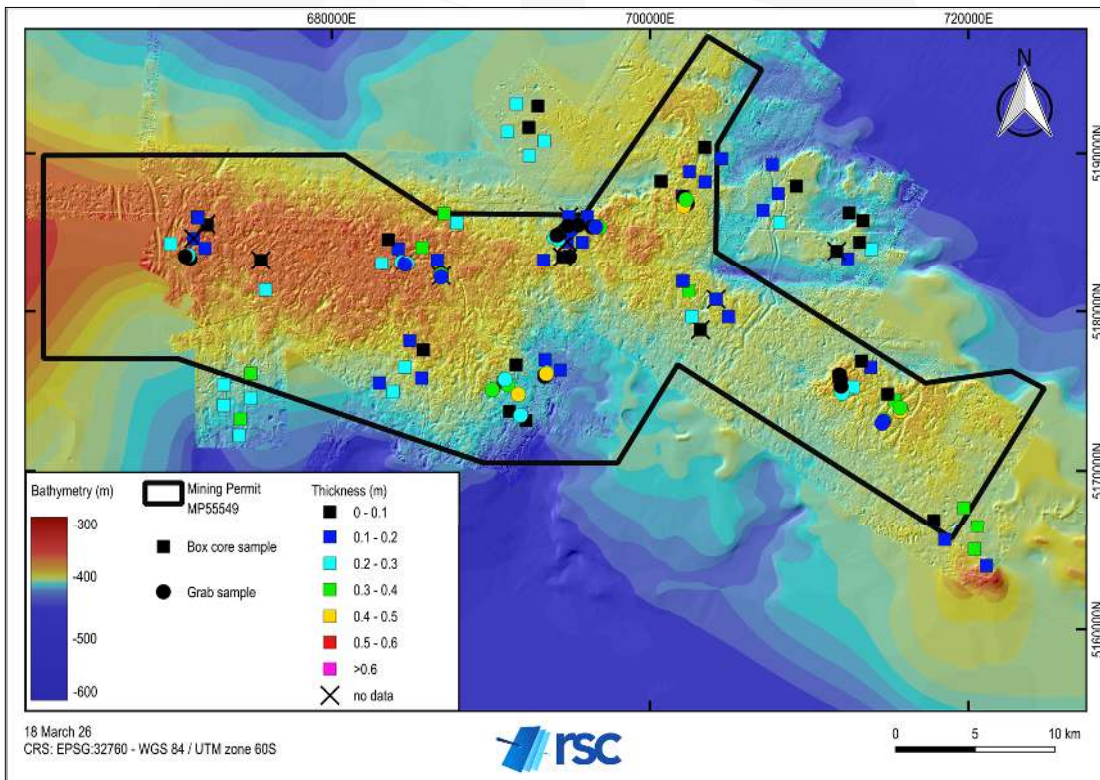


Figure 9-9: RV Dorado Discovery sampling methods, sample locations and penetration depths.

Multiplying the calculated grade of the grab samples by their calculated true depth yields nodule abundances up to 209 Ph kg/m² and averaging 51.7 Ph kg/m². However, the QP notes that although the original nodule abundances calculated for the *RV Dorado Discovery* grab samples were considered likely to be underestimated, these nodule abundances are likely to be overestimated due to the use of a weight percentage in the grade calculation, assumptions of comparable density of sample constituents, and an underestimation of true sediment thickness due to losses during sample recovery (see Section 11.5). Due to the number of assumptions required to calculate grade from the grab sample data, the QP has assigned a low SQR to the samples and excluded them from resource estimations.

In addition to grab samples, 117 box-core samples were collected during the *RV Dorado Discovery* sampling campaign, of which 21 were sieved into >8 mm, 2–8 mm, and <2 mm fractions. The supplied data contain the calculated dry weight percentages of these fractions as well as the original sample wet and dry weights for the samples. As data from the *RV Dorado Discovery* grab samples indicate that >1 mm sieved fractions contain significant constituents other than phosphorite, the QP has factored the dry weight percentages of the >8 mm and 2–8 mm box core fractions down to account for non-phosphorite material in these fractions, using the grab sample sieve data for reference. For the >8 mm fraction of the grab samples, the weight per cent of phosphorite averaged 91% of the fraction weight, and for the 12 measured 0.8–8 mm grab sample fractions, the phosphorite volume per cent averaged 74% (excluding outliers). The box core >8 mm and 2–8 mm sieved fractions were multiplied by these percentages, respectively. The QP notes that this calculation relies on a number of flawed assumptions that give cause for concern in the reliability of the *RV Dorado Discovery* box-core grade calculations. Consequently, the data have been assigned low SQR values and excluded from the resource estimate (see Section 11.5).

Summing the factored weight percentages of the sieved fractions and multiplying by the dry weight of the sieved sample provides an estimation of the contained kilograms of phosphorite in each bulk sample. Dividing this weight of contained phosphorite by the volume of each bulk sample (estimated from the box area, 0.2 m × 0.3 m, multiplied by the thickness of the sediment in the box) yields the sample grade. Using this method, phosphorite grades are up to 707 Ph kg/m³ and average 186.6 Ph kg/m³ for the 21 analysed box cores. Excluding the sediment thickness from the equation allows calculation of the nodule abundance of the samples; this is up to 64 Ph kg/m² and averages 17.9 Ph kg/m².

For the remaining 96 box cores that were not sieved, visually estimated phosphorite percentages recorded for 82 of the samples were the only available data recorded with respect to phosphorite content. Multiplying these values by the average wet density of phosphorite nodules (2.72 g/cm³) yields grade estimates up to 2,720 Ph kg/m³ and average 438.5 Ph kg/m³ for the 82 cores (Figure 9-9). Multiplying grade by the thickness of sediment in the box for each sample yields phosphorite nodule abundances up to 204.0 Ph kg/m² and average 28.5 Ph kg/m². The QP notes that due to the lack of precise measured data for these cores, their calculated grades are of insufficient quality to be included in resource estimations (see Section 11.5).

9.3 Exploration Target — Potential Range of Quantities & Grades

The QP considers the potential to locate additional areas of phosphorite-bearing sand to be significant. In areas immediately adjacent to the Inferred Mineral Resource (refer to Section 14), sampling indicates exploration targets of 15,000,000–

20,000,000 m³, with a phosphorite grade of 200–300 Ph kg/m³ and contained phosphorite target of 3–4 Mt (refer to the area between the solid white and dotted white lines in Figure 9-10) (Table 9-3).

The potential quantity and grade of this global exploration target is conceptual in nature. There has been insufficient exploration to define a Mineral Resource, and it is uncertain if further exploration will result in the target being delineated as a Mineral Resource. The QP notes that the existing sampling in these areas is not of good enough quality or high enough density, and therefore recommends follow-up sampling be carried out if CRP intends to confirm this potential.

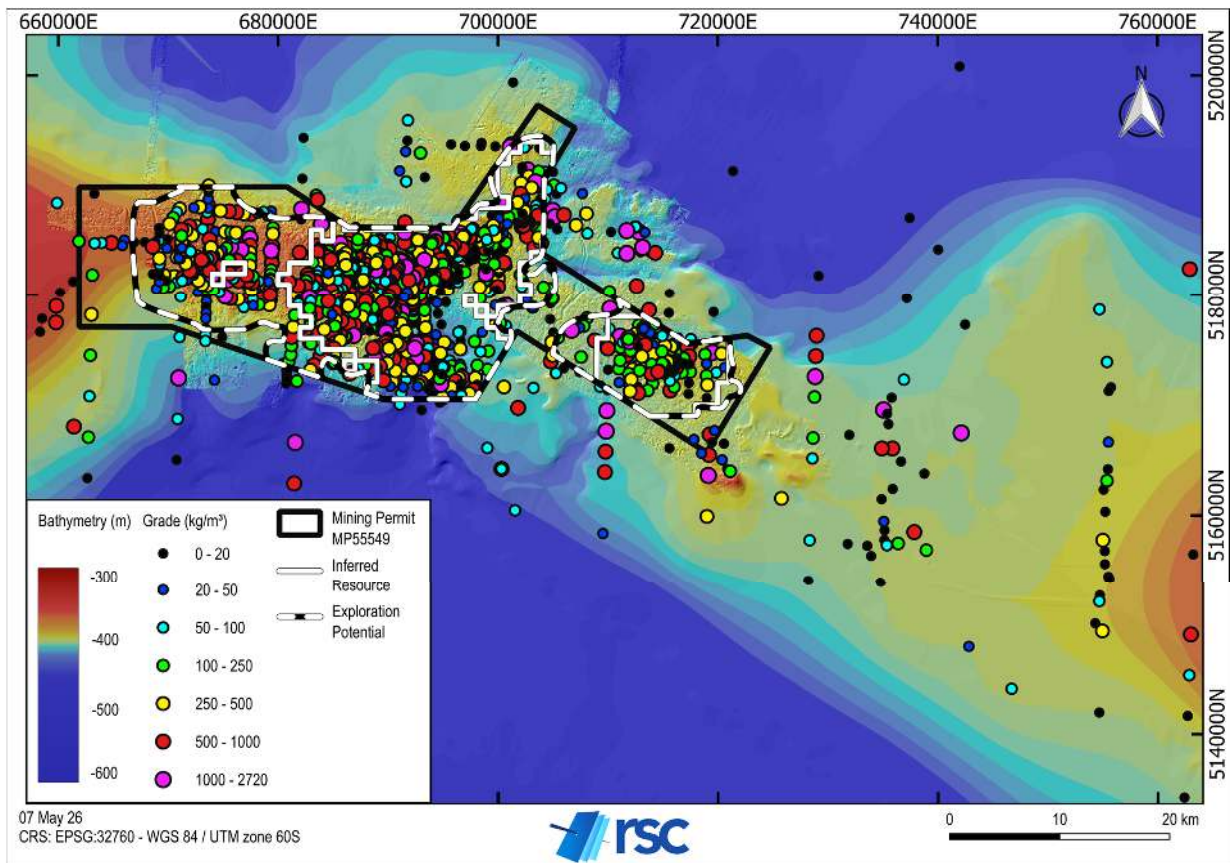


Figure 9-10: Exploration potential and extent of the Inferred Mineral Resource in the Chatham Rise.

Table 9-3: Exploration target and potential range of volumes, grades, and tonnes for phosphorite within CRP tenement MP 55549.

	Potential Range of Volumes (m ³)	Potential Range of Grades (Ph kg/m ³)	Potential Range of Contained Ph (Mt)
Exploration Target	15,000,000 to 20,000,000	200 to 300	3 to 4

Notes:

1. The potential quantity and grade of this exploration target is conceptual in nature. There has been insufficient exploration to define a Mineral Resource, and it is uncertain if further exploration will result in exploration target being delineated as a Mineral Resource.

A prospectivity study by Kenex (2014) aimed to identify the areas of exploration potential in MP 55549 and the wider area. Kenex used the 'mineral system concept' in its study to develop 28 weights of evidence and eight fuzzy logic predictive maps for use in exploration and to assess the prospectivity of the central Chatham Rise for deposition of nodular phosphorite. The fuzzy logic prospectivity modelling was completed to produce targets based largely on derivatives of bathymetry and geology. The model identified low slope angles, entrainment in the saddle regions, and shallow bathymetry with southeast facing slopes as important parameters for nodule deposition on the Chatham Rise. The most prospective regions are likely to be found in the vicinity of major faults and within the very prospective Early Oligocene chalk facies (see Section 7.2).

The model also identified areas where high-grade nodules are least likely to be encountered, i.e. areas containing outcrops of basement and areas with thick covers of Late Neogene, especially Pleistocene, sandy sediments. Prospectivity is also likely to decrease with advancement north or south away from the central crest of the Chatham Rise, where slope angles are steeper, young sediment drapes are thicker, and water depths are likely to have been too deep to allow extensive phosphatisation in the past. The Kenex prospectivity model indicates that the overall mineral endowment may extend further along the Chatham Rise and could be used to inform future exploration efforts.



10. Drilling

As the effective date of the Report, no drilling had been conducted by CRP in the Project area. Phosphorite deposits are essentially two dimensional, with the mineralised material occurring within the top 50 cm of the sea floor. Under normal circumstances, standard grab samplers or box corers sample the entire vertical extent of the mineralisation, negating the need for conventional drilling techniques.



11. Sample Preparation, Analyses & Security

11.1 Sample Preparation & Analysis

11.1.1 MV Tranquil Image Cruise

When the Van Veen sampler was retrieved, water was drained from the closed shell to minimise water in the sample material. The shell was then opened and the sample material collected in a plastic tub. Material that did not fall freely from the sampler was scraped into the tub. Two subsamples were taken from the bulk sample using a shovel. Provided that sufficient material was retrieved, samples from the Van Veen sampler were normally divided into three portions. Two samples of ~5 kg each were placed into sealed plastic bags; one was frozen within several hours of collection and the second was refrigerated. Any remaining sample material was placed in a large, open-topped plastic bag and stored on deck. From the 55 sampling attempts, 45 samples were collected. On the second cruise, the sampling process and the taking of subsamples were witnessed by a consultant geologist on behalf of CRP.

On return to Tauranga (first cruise) and Napier (second cruise), the samples were freighted to the GNS Science facility in Lower Hutt where they were weighed and visually examined. Subsamples were submitted to Waikato University and CRL Energy's Gracefield Laboratory (CRL) for analysis. The Waikato University and CRL facilities are independent of CRP, and both have ISO 17025 accreditation.

Subsamples from 10 grab samples were submitted to Waikato University for analysis. Samples were wet sieved into gravel (>2 mm), sand (2–0.063 mm), and mud (<0.063 mm) fractions. A small representative volume of the mud fraction was analysed using a Malvern Mastersizer 'S' laser diffraction particle size analyser to determine the percentages of silt (0.063–0.004 mm) and clay (<0.004 mm) in the mud fraction. Each fraction was then dried at 50–105°C and weighed to determine the weight per cent of gravel, sand, and mud in each original sample. The sand fraction was then passed through a Frantz magnetic separator three times, with the level of discrimination between magnetic and non-magnetic material increased each time to separate the sand into glauconite-rich and glauconite-poor fractions. These fractions, along with two bulk sediment samples, were weighed and analysed using a Spectro X-Lab 2000 fully automated XRF spectrometer to determine their major and trace element compositions.

Subsamples from 45 of the grab samples were sent to CRL for analysis of grain size distribution. After being washed through a 4-mm screen, the >4 mm fraction was dry sieved and the <4 mm fraction wet sieved, separating the samples into a total of 21 size fractions ranging from <0.063 mm to 100 mm. CRL analysed 73 subsamples of the fractions for major element oxides using XRF.

11.1.2 RV Dorado Discovery Cruises

Upon retrieval of the grab sampler to the ship, the grab sampler was guided into a custom-built cage to hold the grab sampler steady while the sample was observed through openings in the top of the grab and push cores inserted. The grab sampler was then slid into position over the hopper where the sample could be dumped and collected.

The grab samples were observed and logged through openings in the top of the grab sampler. Geologists carried out shear vane tests and then assessed the sample for its suitability for push coring. Grab samples containing concentrations of nodules with little greensand matrix were difficult to core due to the core tube being stopped if the tube edge hit a large nodule. To core, PVC tubes of ~20 cm length were capped in one end and marked with 'up' arrows. The open end was slightly sharpened to give a cutting edge and pushed vertically into the sediment near the centre of the grab sampler, well away from the often-washed-out edges. If necessary, the cores were pushed as far in as possible by standing on them until they sank in fully.

Once preliminary observations and measurements were completed, the grab sampler was emptied over the collection hopper. The bulk sediment was described by geologists, and the push cores were retrieved, capped, and sealed (Figure 11-1). Further subsampling was undertaken for lithological samples; two to four samples (~2 kg each) of the significant lithologies in each grab sampler (including chalk/ooze if present) were collected in clear plastic bags, double bagged, and labelled. Biota samples were collected if specimens were new, particularly well preserved, or exhibited interesting features. All samples were stored on board at 4°C in a temperature-controlled container. Photographs were taken of the sediments in the sample pan. The remaining sample was then scraped into large sample bags for storage. The weights of the bags were recorded before being stored.



Figure 11-1: *RV Dorado Discovery* clamshell grab sample processing.

The focus of the box core sampling on Cruise 3 was ecological assessment rather than resource assessment. Once box core samples were retrieved, the surface characteristics of the sediment were recorded, and two push cores per box core sample were collected for geotechnical and biological assessment. The samples were processed aboard the *RV Dorado Discovery*, with the top 15 cm of sediment being washed through a 500- μ m sieve and the underlying sediment through a 1,000- μ m sieve. Biological specimens were collected, and the biological and sediment samples were both stored in formaldehyde solution. Remaining sediment was bagged for geological analysis. Box cores from Cruise 4 were collected for geotechnical assessment. During Cruise 4, the box corer used had a detachable box so that samples could be weighed and have their bulk density determined prior to removal from the box. The sediment was described by a geologist and sampled in 10-cm intervals by Boskalis' geotechnical engineers.

Vibracores were retrieved by core technicians. When removing the core catcher, any sediment recovered was tagged as 'geo' sample, bagged and labelled, and placed in cold storage. After determining the length of the recovered samples, the cores were marked in 1-m intervals starting from the top and labelled in sequential order. The cores were laid out on a rack for sectioning and cut into the marked lengths using a pipe cutter. After inspection of the exposed ends, the sections were capped and moved to the refrigerated storage. The exceptions were any sections containing greensand and the transition to the chalk; these sections were taken aside for further logging and sampling.

Grab samples from Cruises 2 and 3 were processed after the voyage for geotechnical purposes by GNS Science and Kenex. Samples were separated into three size fractions: >8 mm, 0.8–8 mm, and <0.8 mm. Geological analysis of the >8 mm and 0.8–8 mm fractions was carried out; the <0.8 mm fraction was not studied.

Forty-five >8 mm sample fractions were analysed in detail. The grain lithologies were separated and described, and phosphorite nodules were further classified by size. Each sub-fraction was then weighed to establish their proportion of the total >8 mm fraction weight. After analysis, samples were returned to storage; no special security measures were necessary, and the possibility of contamination or alteration of the samples was deemed extremely unlikely.

The 0.8–8 mm fractions of 12 of the grab samples were submitted to GNS Science where they were air dried and a subsample of the fraction spread out under a stereoscope and observed under ~50 × magnification. Grain types were determined and classified using Power's Roundness Scale and ASTM 2488-00 for grain shape; grains were picked at random until a total of at least 200 grains were analysed per sample.

Samples from box cores collected during Cruise 3 were submitted to Boskalis for detailed analysis of grain size distribution. Samples were dried, weighed and sieved into >8 mm, 2–8 mm, and <2 mm fractions. Sample material from the box cores collected during Cruise 4 of the *RV Dorado Discovery* were assessed for geotechnical parameters by Boskalis.

11.2 Density & Moisture Content

11.2.1 MV Tranquil Image Cruise

Ten samples made up of composited material from 1–4 samples each were submitted to Boskalis Dolman Laboratory for Environmental and Geotechnical Research to test nodule density and water absorption. Between one and six nodules from each composite were tested, for a total of 36 analyses. Sample density was determined using the weight in water and weight in air method. Samples were dried at 110°C for an unspecified length of time to determine their dry density. The samples' dry weights ranged from 1.9–69.8 g. After the exclusion of two outliers, the samples yielded an average dry density of phosphorite nodules of 2.65 g/cm³, an average wet density of 2.72 g/cm³, and average water absorption of 2.8%.

Boskalis Dolman Laboratory for Environmental and Geotechnical Research is independent of CRP and is accredited under ISO standards 9001, 14001, and 45001.

11.2.2 RV Dorado Discovery Cruises

Push core samples collected from the grab samples yielded an in-situ sample of the phosphorite-bearing glauconitic sand, which was analysed for density. The samples were sealed to retain the moisture content before analysis by Boskalis in the Netherlands. Density tests were conducted using the New Zealand Standard for soil testing NZS 4402.5.1.3:1986 (Soil density tests - Determination of the density of soil - Test 5.1.3 Sampling tube method for the determination of the in-situ density). Due to higher concentrations of phosphorite nodules inhibiting core penetration into the sediment, the cores retrieved are biased toward samples from fuller grab samplers containing less phosphorite.

Density analyses from the *RV Dorado Discovery* samples are summarised in Table 11-1. Analysis of the 44 push cores yielded bulk densities that ranged from 1.26–2.15 g/cm³, with an average of 1.63 g/cm³. Bulk density (nodules plus void space between nodules) analysis was also conducted on the >8 mm sieved fractions of seven grab samples and the 0.8–8 mm sieved fractions from five grab samples. Most of the fractions are described as being ‘clean nodules’, with three also containing ‘few limestones’ or ‘some shells’. Excluding one coral-rich outlier, the >8 mm and 0.8–8 mm fractions had bulk density ranges of 1.57–1.68 g/cm³ and 1.54–1.77 g/cm³, respectively.

Table 11-1: Bulk sediment and bulk nodule densities determined from *RV Dorado Discovery* samples.

Sample type	Average Wet Bulk Density (g/cm ³)	Number of Samples
Push core bulk sediment	1.63	44
Bulk phosphorite nodules >8 mm	1.57–1.68	5
Bulk phosphorite nodules 0.8–8 mm	1.54–1.77	5

11.3 Security

11.3.1 MV Tranquil Image Cruise

No special security measures were taken with respect to the collection and storage of samples from the *MV Tranquil Image* Cruise as this was not necessary.

11.3.2 RV Dorado Discovery Cruises

No special security measures were taken, as the possibility of contamination or alteration of the samples was deemed extremely unlikely.

11.4 Data Quality

Every data collection process implicitly comes with expectations for the accuracy and precision of the data being collected. Data quality can only be discussed in the context of the objective for which the data are being collected. In the minerals industry, the term ‘fit for purpose’ is typically used to convey the principle that data should suit the objective. In the context of data quality objectives (DQOs), fit for purpose could be translated as ‘meeting the DQOs’.

For CRP, the quality of the samples and associated data needs to be fit for the purposes of classifying Mineral Resources in at least the Inferred category, in accordance with the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) guidelines (CIM, 2019).

11.4.1 MV Tranquil Image Cruise

Only a basic description of the sampling process was available for review. The process described does not explain the steps to be taken to prevent sample bias or to control the accuracy and precision of measurements and calculations. No information was available on the method of subsampling prior to sieving; therefore, the procedures followed are unclear, and the QP is unable to determine whether the processes were always in control. The QP notes that the practice of removing subsamples for various onshore tests resulted in the original sample being reduced in size in a manner that is likely to add further error and possibly introduce bias to calculated phosphorite grades.

The QP estimated grade for the samples by multiplying the dry phosphorite weight percentages (assumed to be equivalent to the >2 mm dry weight percentage) of the samples by the average dry density of phosphate nodules. Although this calculation may remove the error associated with calculating contained kilograms of phosphorite from a sample that has previously had material removed, it assumes that the sieved portion of the grab sediment is composed entirely of phosphorite and proportionally representative of the >2 mm fraction of the bulk sediment prior to subsampling. In addition, using a dry weight percentage assumes that all the constituents of the bulk sediment have the same density, which is demonstrably not the case, and will therefore yield calculated grades that are significant overestimates of true grade. As grab samples were not processed in their entirety and data on the weight, volume and moisture content of the sieved samples were not included in the supplied analysis data, reliable phosphorite grades cannot be determined for the *MV Tranquil Image* samples.

The QP has a number of concerns with the *RV Dorado Discovery* grab sampler and box core sample processing data. Previous calculations of the nodule abundance of the grab samples assumed all of the sediment in the >8 mm and 0.8–8 mm fractions was phosphorite. Although the data indicate that phosphorite is the dominant constituent in both fractions for most of the samples, non-phosphorite sediment constituents (such as shells, erratics, and other lithics) are known to be present in the samples but have not been accounted for. The QP attempted to limit the error introduced by this assumption by using the available constituent data for the sieved fractions (Berthelsen et al., 2012; Nielsen, 2012c) to estimate the actual phosphorite content of the sieved fractions. As some of the sediment in each grab sample was not sieved, the calculated phosphorite content (kg) is likely to be an underestimate of the total amount of phosphorite at any given sample location, which when divided by the sample area of the grab sampler will yield a nodule abundance lower than the actual nodule abundance for that sample. Grades determined from these data assume that the material processed by sieving was representative of the original bulk grab sample.

Due to the sieved fractions of the grab samples being processed in different ways (weight percentage data were collected for the >8 mm fraction and constituent grain percentage for the 0.8–8 mm fraction, and not for every sample). The observed relationship between the phosphorite content of the >8 mm fraction and the 0.8–8 mm fraction for which both fractions were assessed was used to estimate the phosphorite content in the 0.8–8 mm fraction for samples without this data recorded.

Determining the phosphorite content of the >0.8 mm fraction of grab samples subsequently assumes the density of all the constituents, both phosphorite and non-phosphorite, are the same. As the phosphorite grade of the samples was calculated by relying on a number of flawed assumptions and imprecise relationships between the sieved fraction data, the calculated grades for the *RV Dorado Discovery* grab samples are unreliable. The QP has assigned a lower SQR to those data, allowing them to be identified and restricted from being used in resource estimation.

With respect to the *RV Dorado Discovery* box core samples, the QP notes that applying a volume per cent to a weight per cent in the case of the 2–8 mm sieved fraction assumes that the density of all constituents is the same, which is not the case. The QP also notes that the difference between the sieved fraction ranges of 0.8–8 mm (grab sampler) and 2–8 mm (box core samples) means that using the volume per cent of phosphorite from the grab samples to proportion the weight per cent of phosphorite in the box core samples is likely to be inaccurate and lead to an underestimation in grade as it does not take the removal of the 1–2 mm sand fraction (assumed to be comparatively phosphorite poor) from the box core sieved fraction into account. This is in contrast to the overestimation in grade expected if no correction factors are applied.

The QP further notes that as push cores had already been collected from the box core samples prior to processing, calculated contained kilograms of phosphorite may be less than the total amount of phosphorite that was in the original sample. Similarly, dividing this value by the volume of the box corer sample rather than the volume of the sieved sample means that the calculated grades for the 21 measured box-core samples would, in the absence of other errors, lead to an underestimation of true grade. The errors and assumptions inherent in the calculation of the grades of these samples make them unreliable and consequently they have been assigned low SQR and excluded from the resource estimation.

11.4.2 *RV Dorado Discovery* Cruises

Detailed descriptions were available of the sampling process itself; however, there were several flaws in the procedures and equipment used. No duplicate samples were collected for quality control analysis; therefore, the QP cannot confirm whether the processes were in control, and the accuracy and precision of the data cannot be assessed.

The QP has a number of concerns about the *RV Dorado Discovery* grab sampler and box-core sample processing data. Previous calculations of the nodule abundance of the grab samples assumed all of the sediment in the >8 mm and 0.8–8 mm fractions was phosphorite. Although the data indicate that phosphorite is the dominant constituent in both fractions for most of the samples, non-phosphorite sediment constituents (such as shells, erratics, and other lithics) are known to be present in the samples but have not been accounted for. The QP attempted to limit the error introduced by this assumption by using the available constituent data for the sieved fractions (Berthelsen et al., 2012; Nielsen, 2012c) to estimate the actual phosphorite content of the sieved fractions. As some of the sediment in each grab sample was not sieved, the calculated phosphorite content (kg) is likely to be an underestimate of the total amount of phosphorite at any given sample location, which when divided by the sample area of the grab sampler will yield a nodule abundance lower than the actual nodule abundance for that sample. Grades determined from these data assume that the material processed by sieving was representative of the original bulk-grab sample.

Due to the sieved fractions of the grab samples being processed in different ways (weight percentage data were collected for the >8 mm fraction and constituent grain percentage for the 0.8–8 mm fraction, and not for every sample). The observed relationship between the phosphorite content of the >8 mm fraction and the 0.8–8 mm fraction for which both fractions were assessed was used to estimate the phosphorite content in the 0.8–8 mm fraction for samples without these data recorded. Determining the phosphorite content of the >0.8 mm fraction of grab samples subsequently assumes the density of all the constituents, both phosphorite and non-phosphorite, are the same. As the phosphorite grade of the samples was calculated by relying on a number of flawed assumptions and imprecise relationships between the sieved fraction data, the calculated grades for the *RV Dorado Discovery* grab samples are unreliable. The QP has assigned these data a lower SQR, allowing them to be identified and restricted from being used in resource estimation.

With respect to the *RV Dorado Discovery* box core samples, the QP notes that applying a volume per cent to a weight per cent in the case of the 2–8 mm sieved fraction assumes that the density of all constituents is the same, which is not the case. The QP also notes that the difference between the sieved fraction ranges of 0.8–8 mm (grab sampler) and 2–8 mm (box core samples) means that using the volume percent of phosphorite from the grab samples to proportion the weight per cent of phosphorite in the box core samples is likely to be inaccurate and lead to an underestimation in grade as it does not take the removal of the 1–2 mm sand fraction (which is typically comparatively phosphorite poor) from the box core sieved fraction into account. This is in contrast to the overestimation in grade expected if no correction factors are applied.

The QP further notes that as push cores had already been collected from the box core samples prior to processing, calculated contained kilograms of phosphorite may be less than the total amount of phosphorite that was in the original sample. Similarly, dividing this value by the volume of the box corer sample rather than the volume of the sieved sample means that the calculated grades for the 21 measured box-core samples would, in the absence of other errors, lead to an underestimation of true grade. The errors and assumptions inherent in the calculation of the grades of these samples make them unreliable and consequently they have been assigned low SQR and excluded from the resource estimation.

11.4.3 Quality Acceptance Testing

Quality acceptance testing (QAT) is where a final judgement of the data is made by assessing the accuracy and precision of the data for those periods where the process was demonstrated to be in control, and separately for those periods where the process was demonstrated to be not in control. Accuracy and precision are evaluated, and a final pass/fail assessment is made based on the DQO.

No quantitative quality data were available for samples collected on either of the cruises; therefore, accepting the quality (accuracy and precision) of the data based on statistically defined thresholds is not possible. In the absence of such data, the QP has determined an SQR for all available datasets from the *MV Tranquil Image* and *RV Dorado Discovery* cruises as a relative check to identify low-quality data for exclusion from the MRE, and remaining data are assumed fit for the purposes of classifying an Inferred Mineral Resource in accordance with the CIM guidelines (CIM, 2019).

11.5 Sample Data Quality Ranking

The overall quality of the data was assessed in as much detail as practicable. This is a critical part of the assessment of the data, as it depicts the quality threshold to either allow or disallow data to be used in the estimation process. Across and even within the various sampling campaigns, different sampling, subsampling, logging, volume and depth measurements, grade calculations, and location measurements have occurred, and a matrix was constructed to rank the impact of all these factors and assign each sample an SQR (Figure 11-2 and Table 11-2). Quality assurance and quality control measures varied significantly between the various campaigns.

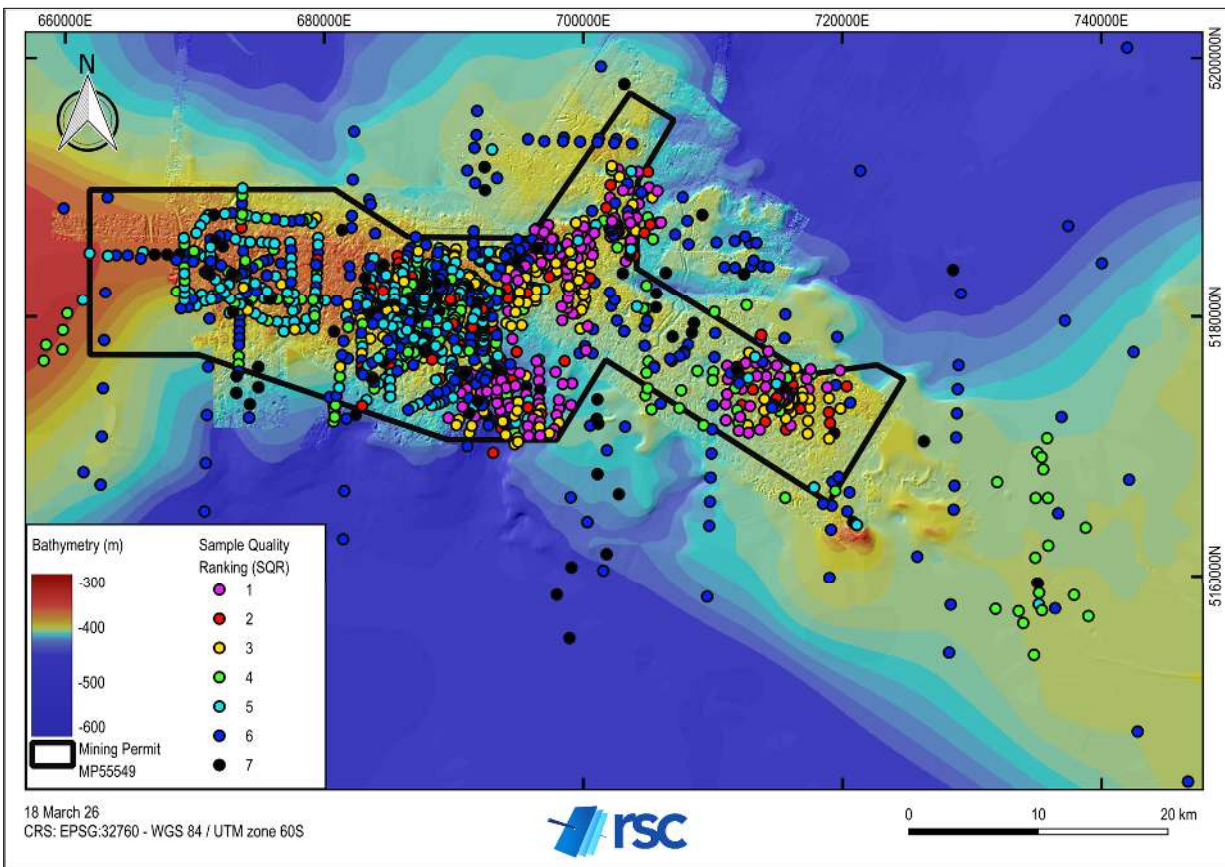


Figure 11-2: Sample location and Sample Quality Ranking values.

Table 11-2: Description of Sample Quality Ranking assignment.

SQR	CATEGORY DESCRIPTION	NUMBER OF SAMPLES					
		GLOBAL MARINE	TANGAROA	VALDIVIA	SONNE	TRANQUIL IMAGE	DORADO DISCOVERY
1	SONNE only; grab samples, ATNAV, chalk present (sampled full profile), not full bucket (assume ~100% recovery)				208		
2	SONNE: grab sample, ATNAV, no chalk (not sampled full profile), not full bucket (assume ~100% recovery) VALDIVIA: large grab sample, ATNAV, <5% difference in volume from modelled, not subsampled for sieving			37	50		
3	SONNE: grab sample, ATNAV, full bucket (possible sediment loss/sampling bias) or minor data inconsistencies VALDIVIA: large grab sample, <10% difference in volume from modelled, not subsampled for sieving; OR small grab sample, ATNAV, <5% difference in volume from modelled, not subsampled for sieving			67	118		
4	SONNE: grab sample, SATNAV, chalk present or absent, partial or full bucket VALDIVIA: large or small grab sample, ATNAV or SATNAV, <15% difference in volume from modelled, subsampled for sieving or not			102	113		
5	SONNE: grab sample, SATNAV, data inconsistencies, calculated bulk sample density <1 or >3 g/cm ³ VALDIVIA: large or small grab or box core sample, ATNAV or SATNAV, >15% but <40% difference in volume from modelled DORADO DISCOVERY: box core sample, GPS, average PH% factored fraction weight %			278	19		22
6	SONNE: any kind of sample, washed out sample, ATNAV or SATNAV VALDIVIA: large or small grab sample, washed out sample or >40% difference in volume from modelled, ATNAV or SATNAV TRANQUIL IMAGE: grab sample, PH% >2mm fraction recorded DORADO DISCOVERY: box core sample, visually estimated PH% only; OR grab sample GLOBAL MARINE: dredge sample, non-validated data, estimated PH% TANGAROA: box core sample, non-validated data, measured PH weight % or visually estimated PH%	320	18	136	4	45	124
7	ALL: successful samples with non-usable data (no PH% recorded, no location data); OR samples that failed due to technical failure	17	35	69	37	10	67
TOTAL SAMPLES:		337	53	689	549	55	213

The best-quality samples were typically those that were collected using the pneumatic grab sampler, sampled the full sand horizon, had high survey accuracy, and had no other apparent data ambiguities. These samples were large and representative, with appropriate and consistent measurements. The QP considers samples collected during the *RV Sonne* cruise to be of the highest quality, followed by some of the *RV Valdivia* samples and then the box core samples from the *RV Dorado Discovery* cruise. The best-quality samples were assigned a ranking of 1, and the worst-quality samples were

assigned a rank of 7. Samples ranked 5–7 were not included in the resource estimation. Samples classified as 7 include samples that failed due to technical failure, samples with no recovered sediment due to technical failure, samples collected but no data recorded (phosphorite per cent, weights, or location), and samples with no location coordinates. Samples classified as 6 include non-validated data, samples documented as washed out, or otherwise biased samples. Samples classified as 5 include validated samples with acceptable location accuracy but with demonstrated unacceptable bias in the grades due to suspected washing of the samples or errors in visual estimation of the grade.

The QP considers pneumatic grab sampling to be the best possible sampling mechanism for this deposit. This type of sampling collects a large sample and therefore suitably deals with the high sample variance (within the boundaries of practicalities). The pneumatic system provides a good control on the representativeness of the sample. Core drilling has been considered and attempted for this deposit but would collect a much smaller sample and is impractical, as the underlying ooze and chalk layers are difficult to core, resulting in lost core and lost equipment.

The QP considers sample data collected from the *RV Valdivia* and the *RV Sonne* that have been assigned an SQR of 1–4 (inclusive; see Figure 11-2) to be of sufficient quality for the classification of Inferred Mineral Resources.

11.6 Summary

The QP notes several concerns with the sampling process used on the *MV Tranquil Image*. Potential sample bias and assumptions affecting the *MV Tranquil Image* samples include:

- the Van Veen sampler was not mechanically controlled and lacked the ability to sample the entire nodule-rich sediment layer; no weights were used to facilitate greater penetration as was done with *RV Valdivia* sampling;
- nodules/erratics could get caught in the Van Veen jaws, resulting in the sample being washed out;
- the Van Veen grab sample volume is too small to reliably sample the thickness and style of deposit;
- penetration depths were not documented;
- some subsampling has taken place on the ship, but it is not known whether these subsamples are representative of the samples;
- it is not clear from the sample data if the phosphorite weight percentages have been calculated from the whole sample or a subsample, and moisture content has not been adjusted for in calculating these weight percentages,
- the phosphorite grade of the samples has been estimated using dry sieved weight percentages for sieved material over 2 mm and proportioned against the wet weights, resulting in an over estimation of grade; and
- it has been assumed that all material >2 mm is phosphorite.

The QP also notes several concerns with the sampling process used on the *RV Dorado Discovery*. Potential sampling bias and assumptions affecting the *RV Dorado Discovery* samples include:

- all grab samples have been exposed to some degree of washing, which results in loss of fines and overestimation of phosphorite concentration; the samples are therefore likely biased to higher grades;
- phosphorite estimation for the grab samples is based on a weight per cent phosphorite in the >8 mm size fraction, and assumes density is the same for all constituents in the fraction;

- phosphorite volume percentages for the 0.8–8 mm grab sample fractions were determined by point counting very small subsamples of the total sediment fraction, and there is a risk the small samples were not representative of the bulk sediment fraction;
- phosphorite volume percentages for the 0.8–8 mm grab sample fractions were only quantitatively determined for 12 of the 45 successful grab samples, and the remainder were estimated based on a poorly constrained relationship between the amount of phosphorite in each sieved fraction;
- the QP has estimated the volume of the large grab based on dimensions provided by Simon Nielsen and images of the grab sampler;
- the QP has assumed that the volume cut into the seafloor with the sampling method is a vertical-sided cut, with equal depth across the sample, and no curved edges or central ridge of sediment left behind where the jaws close; based on the sample volume of 1.31 m³, the maximum depth sampled can be 47 cm (assuming no sample loss);
- box core penetration depths have been visually estimated;
- grade estimations from the box core data assume that the constituents of the >8 mm sieved fractions have the same density; and
- correction factors for phosphorite content in the box core sieved fractions assume that the grain size distribution of sediment is comparable between samples collected by the different grab sampler and box core methods, and that the sieved fractions are equivalent despite different mesh sizes (>8 mm and 0.8–8 mm for grab samples and >8 mm and 2–8 mm for box core samples).

The QP has only partially validated the sample data from the *MV Tranquil Image* and *RV Dorado Discovery* cruises. For all datasets, samples have been assigned SQR values, but due to the incomplete record of sample processing results, the samples have been assigned low quality rankings and have not been included in the data used for the resource model (Section 11.4).

12. Data Verification

The QP confirms that at the effective date of the Report, no material work had been conducted on the Project since the QP's visit to CRP's subsampling site in January 2014. To verify this, the QP discussed the Project's progress with CRP, and reviewed public announcements made by CRP.

12.1 Data Verification Procedures

A digital database was supplied to the QP by consultants from Kenex Knowledge Systems Ltd (Kenex) who had been involved with the data management from the start of the Project and data collection for the *RV Dorado Discovery* cruises. Compilation of the database was a collaborative effort by Kenex and NIWA. NIWA compiled the *RV Valdivia* and *RV Sonne* data from hard-copy maps and scanned sample sheets. The Global Marine, *MV Tranquil Image*, and *RV Dorado Discovery* data were later added by Kenex. No data were compiled from the *RV Tangaroa* cruise, and these have been sourced from Cullen (1978). Kenex added calculation fields from the historical data to further analyse sample grade estimations and prospectivity analyses.

The data were stored in Microsoft Access tables and exported by the QP into flat Microsoft Excel tables to facilitate verification.

In addition to the Microsoft Access database, the following data were provided to the QP from each cruise.

RV Valdivia Cruise: 1978

Scanned copies of the raw data sheets for all 689 samples collected aboard the *RV Valdivia* were made available to the QP. The information recorded on these sheets included sample number, sample apparatus, penetration depth and/or sample volume, as well as a brief shorthand geological description using prescribed logging codes that included a rough estimate of phosphorite content. A search of archived material at BGR by Dr Hermann Kudrass, scanned copies of hand-written data tables detailing the sample number, presence/absence of ooze, volume of sample that was processed by sieving, volume of >1 mm sieved fraction, estimated phosphorite content (%) of the >1 mm fraction, maximum phosphorite nodule size, and calculated phosphorite volume percent for each sieved sample were located. This information was duplicated on a printout of an old digital database found with the hand-written data tables, with a few historical corrections having occurred between the sheets. It is not clear whether the hand-written data tables are the original field sheets on which sieve data were recorded. These hand-written data sheets also record information on the grain size distribution of 65 samples sieved into >32 mm, 16–32 mm, 16–8 mm, 8–4 mm, 4–2 mm, and <2 mm fractions; however, the records of these fractions are barely legible.

RV Sonne Cruise: 1981

Scanned copies of the raw data sheets for all 550 samples collected aboard the *RV Sonne* were available. The information recorded on these sheets included the sample number, sample apparatus, penetration depth, sample weight, sand/chalk thickness, sieved fraction weights, phosphorite percent, and shorthand geological description. The shipboard analyses

sheet included all of the above details plus phosphorite weight per cent, phosphorite nodule abundance (kg/m^2), and simple geological logs. The ship station sheet included all positioning recording and times used for the location of the samples.

MV Tranquil Image: 2011

Copies of the IXSurvey reports detailing the cruise activity and samples taken were provided. Data in these reports included the sample number, sample location, depth to sample, sample method, a photograph, and a brief sample description. Separation, density, and geochemical analyses were supplied as individual Microsoft Excel files.

RV Dorado Discovery: 2011–2012

Copies of the CRP *RV Dorado Discovery* cruise reports detailing cruise activity and collected samples were provided. Data in these reports included the sample number, sample location, depth to sample, grab sampler fill per cent, bag weight, glauconitic sand per cent, nodules per cent, nodules maximum size, a brief geological description, and shear strength. Separation analyses were also received from CRL in the form of Microsoft Excel files.

The QP conducted a thorough validation of the *RV Valdivia* and *RV Sonne* data and a best-possible validation of the *MV Tranquil Image* and *RV Dorado Discovery* data.

The review of the *RV Valdivia* data was limited to the available data presented on the raw sample sheets, and a tabulated record dating from the time of the cruise recording the results of the shipboard processing. The raw data sheets for sieving were unavailable. Combined, these data recorded sample penetration depth, sample volume, geological descriptions, presence/absence of foraminiferal ooze, volume of samples/subsamples that were sieved, volume of >1 mm sieved fraction, visually estimated phosphorite content of >1 mm sieved fraction, maximum phosphorite nodule diameter, and calculated phosphorite volume per cent. The QP validated the recorded values for penetration depth, sample volume, sieved >1 mm fraction volume, and estimated phosphorite per cent with values in the database.

The review of the *RV Valdivia* data revealed the following inconsistencies:

- transcription errors between the written sample sheets and the database;
- missing data;
- minor calculation errors between fields; and
- rounding errors.

All inconsistencies were either resolved or the ranking of the sample quality appropriately downgraded. The QP has not validated other *RV Valdivia* data collected on the cruise.

The review of the *RV Sonne* data revealed of the following data inconsistencies:

- transcription errors between the written sample sheets and the database;
- missing data;
- minor calculation errors between fields;
- rounding errors; and
- grade calculations being inconsistent with documented methods.

All inconsistencies were either resolved or the SQR appropriately downgraded. The QP has validated the *RV Sonne* data, and these numbers have been used in updated grade calculations. The QP has not validated other geotechnical, geochemical, and geophysical data collected during the *RV Sonne* cruise.

The QP validated 10% of the *RV Dorado Discovery* and *MV Tranquil Image* data and found no significant issues. Data from the *Global Marine* and *RV Tangaroa* work have been accepted at face value, as original data were not available. None of the *Global Marine* or *RV Tangaroa* data have been included in the resource estimation.

12.2 Visual Verification of Nodules

During Cruises 2, 3, and 4 on the *RV Dorado Discovery*, an ROV was deployed and images recorded from the seafloor in a number of detailed transects with a rough station spacing of 1–20 m. Data collected included the occurrence of phosphorite nodules on the surface of the seafloor. Where nodules were observed, they were described further with an average size and overall abundance.

The QP attempted to determine whether there is a relationship between nodule abundance and the phosphorite grade of the nearest samples with doubtful sample quality rankings. However, with the lack of suitably close samples, a positive correlation between phosphorite grade and counted slides of phosphorite abundance could not be demonstrated. The ROV images confirm the existence of phosphorite nodules at a few *RV Dorado Discovery* sample sites, as presented in Figure 12-1 and Figure 12-2. These images also demonstrate the visual differences between higher-grade and lower-grade sites. Importantly, along the ROV sample line transects, the images and nodule counts also confirm the high short-range variability of the sample grades.

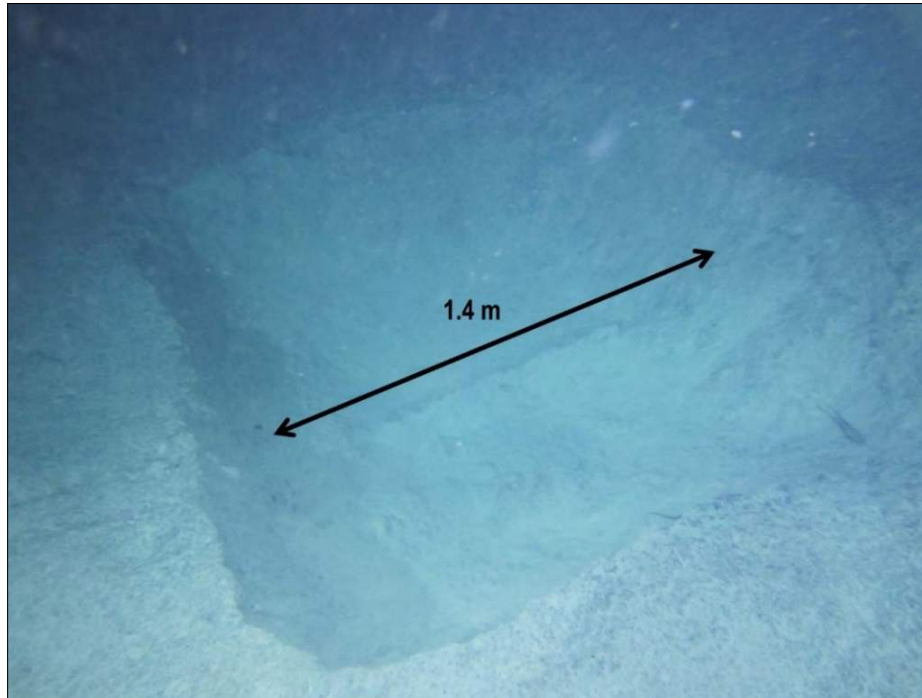


Figure 12-1: Grab sample site for DD016 (193 Ph kg/m³).

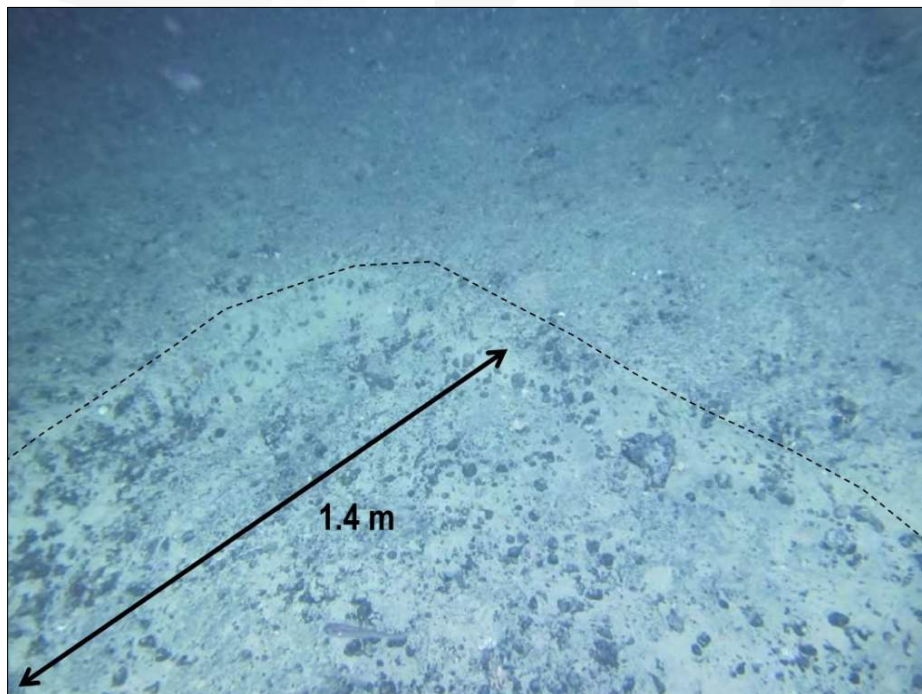


Figure 12-2: Grab sample site for DD025 (695 Ph kg/m³).

12.3 CPT Depth Data vs Sample Depth

CPTs were conducted in the Project area during the third *RV Dorado Discovery* cruise. In total, 125 tests were conducted along 26 transects at a 50-m spacing (Figure 12-3). The QP assessed CPT results along each transect with respect to the interpreted thickness of glauconitic sand and the variability of that thickness along each transect. The results indicated that sand depths were often considerably thicker than the sample depths determined by seafloor sampling (average 0.23 m), with an average sand depth of 0.47 m (maximum 2.27 m). However, the CPT data include several mixed populations, with the main population ranging from 10–40 cm in thickness (Figure 12-4). When a full bucket was collected in the sampling programmes, the thickness was set to the maximum penetration depth of the bucket, although the sediment could have been much thicker, as demonstrated by the CPT data. This needs to be taken into consideration when comparing the averages between the sample depths and CPT depths.

The CPT data indicate that the base of the sand is typically deeper than the depths obtained from sampling, suggesting additional exploration potential. The MRE presented in section 14 is based on the thickness determined from the sampling, which was limited to the top 40 cm. Although current mining concepts focus on resources in the top 30–40 cm of the sand unit, additional resources could be developed at depths >40 cm if these zones are found to host economic phosphorite grades (Figure 12-5). The quality of the CPT depth data has not been validated by the QP, and the data were not used in the resource estimation.

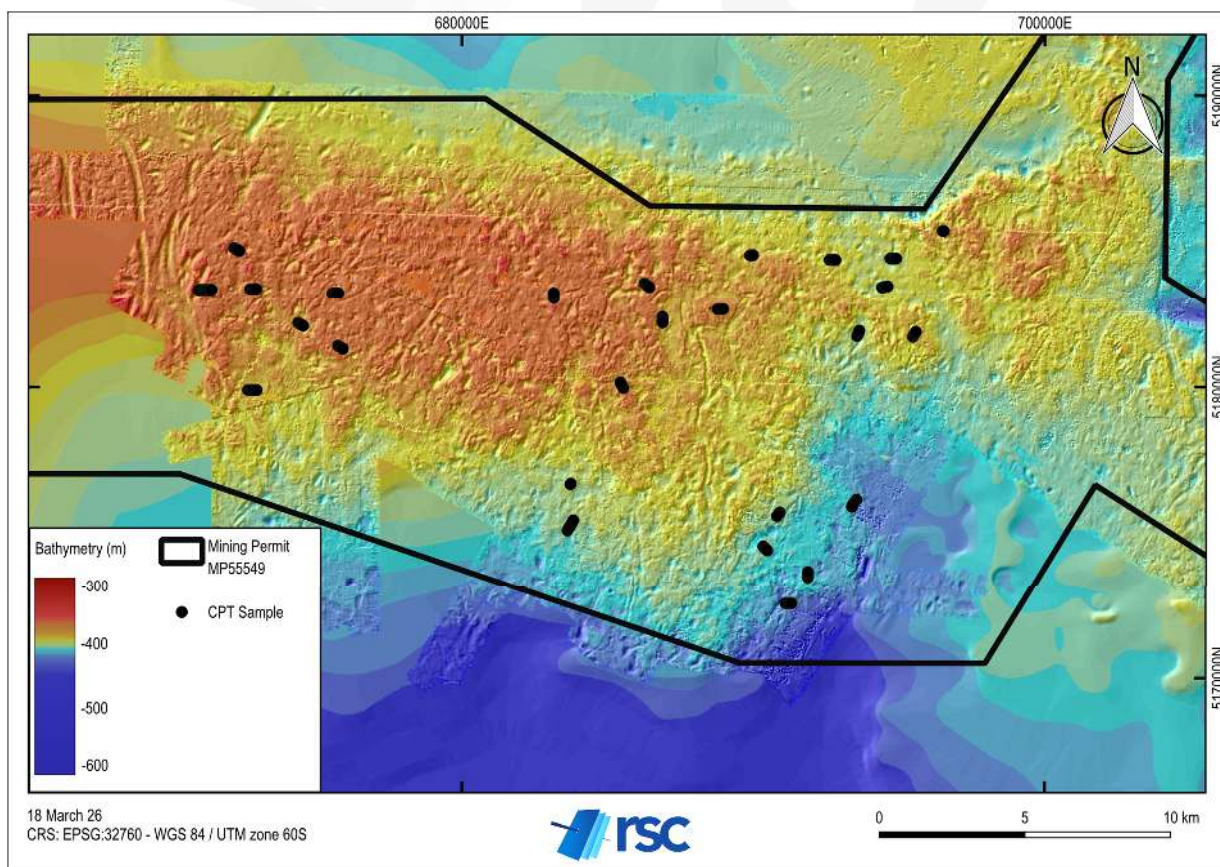


Figure 12-3: CPT sample areas (black dots).

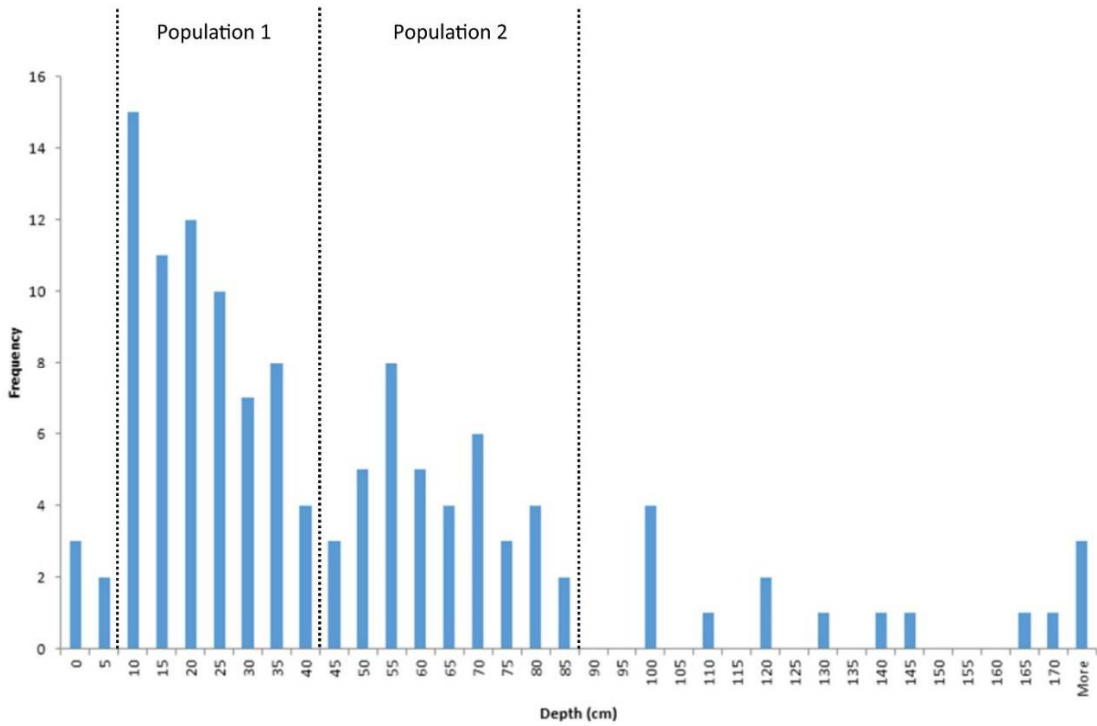


Figure 12-4: Histogram of CPT depth data. Mixed populations indicate two or more areas with different thickness. The dominant depth ranges from 10–40 cm, which is consistent with the sampling data.

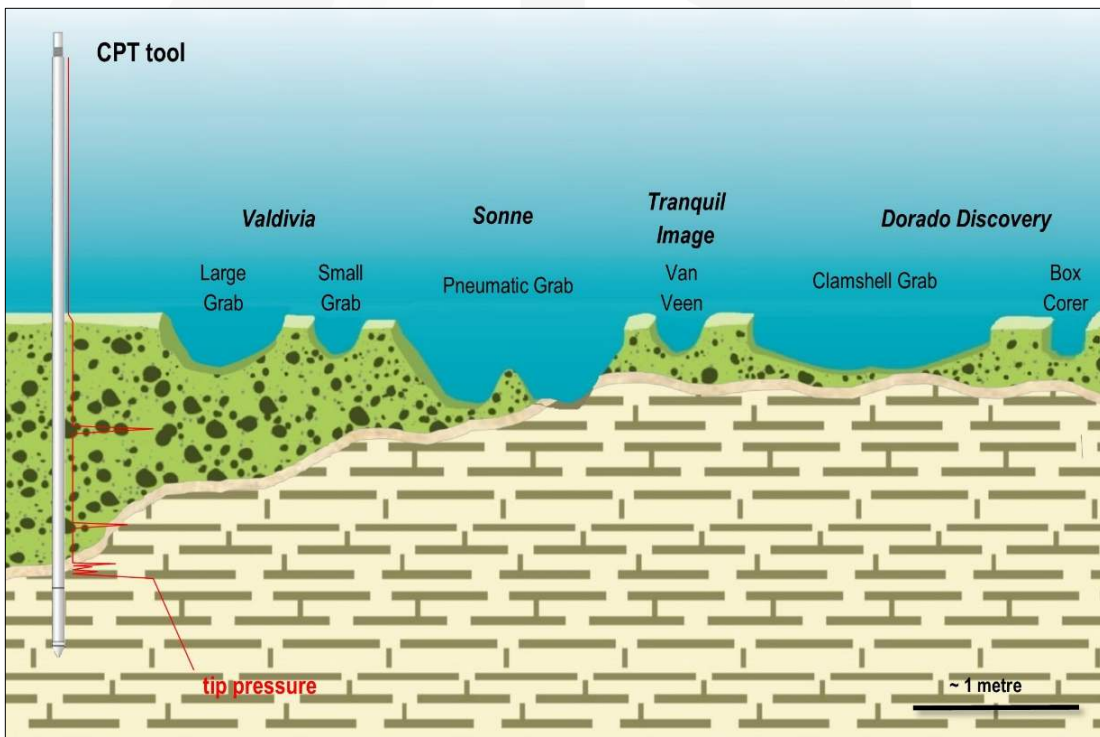


Figure 12-5: Schematic sand and chalk profile with potential tonnages below the sampled depth.

13. Mineral Processing & Metallurgical Testing

13.1 Beneficiation

The QP considers that the phosphorite material to eventually be mined from the Chatham Rise is a bulk product that will be sold to customers in its recovered raw state. Recoveries of the phosphorite resource from the seafloor will be controlled by the dredging (mining) process and all material received at the ship will be processed through a separation plant, with the >2 mm fraction retained and stored in the ship's hold.

The final product would be an unsorted >2 mm size fraction recovered from the seafloor and will include shell, chalk, limestone and other rock fragments. These components will be a diluting factor for the final phosphorite grade. The *RV Sonne* data indicate that the average visual estimation of non-phosphorite content in the >1 mm fraction is 15 volume percent (samples with no phosphorite were not counted). It is noted that the density of the impurities is less than the phosphorite nodules and therefore by weight percentage, this number is expected by the QP to be lower.

CRP has conducted several beneficiation tests. Grinding and flotation tests were carried out by Mintek in 2011 and results indicated beneficiation of <1 wt% P_2O_5 with an 88.6% recovery into a concentrate. The difference in P_2O_5 content between the concentrate and tailings is about 1 wt% P_2O_5 , which Johnston (2013) suggests is because the conventional grinding and flotation process is not suitable for beneficiating the P_2O_5 levels in the Chatham Rise ore.

A laboratory-scale study by Johnston and Tate (2013) on one sample from the *RV Dorado Discovery* cruise (DD06) demonstrated that the preferred beneficiation conditions for increasing the P_2O_5 grade of the ground Chatham Rise ore by calcination and ensuing acetic acid leaching are flash calcination of the Chatham Rise ore for ten minutes followed by quenching before leaching with 0.1 M acetic acid at a ratio of 1:4 solid ore to acetic acid for a period of 30 minutes. This should beneficiate the P_2O_5 by ~6–7% to give a final P_2O_5 grade of 27–28 wt%. However, this process is not being considered due to the predicted high processing costs.

13.2 Grain Size Separation

Boskalis investigated the implications of minimum grain separation scenarios (Figure 13-1). As the cut-off size increases, the percentage of material retained decreases, but the remaining grade of the concentrate increases. At the originally intended separation system cut-off was 1 mm, the effective retention of phosphorite material brought onto the vessel would be ~96%; only 4% would be lost and returned to the seabed. However, the product produced would contain 64% rock phosphorite and 36% impurities (erratics, chalk, biological organisms). Separation at 2 mm would reduce the retention to ~92%, with 8% returned as tailings. However, the quality of the product improves, as ~73% of the retained material would be rock phosphorite, with 27% impurities. It is not clear which samples this work was carried out on, and whether they are representative of the mineral resource. The QP therefore does not consider the diluting percentages reported by Boskalis to be comparable with the visual estimation of impurities from the *RV Sonne* data. Rather, they are the result of tests on a single non-representative sample.



Figure 13-1: Separation scenarios.

13.3 Major Element Geochemistry

Analyses were completed for major element chemistry and trace elements on both *RV Valdivia* and *RV Sonne* samples in two size fractions >8 mm and 1–8 mm (Kudrass & Cullen, 1982; Kudrass, 1984). These demonstrated significant correlation of chemistry with nodule size (Table 13-1). Larger nodules had lower P₂O₅ and higher CaO contents than the smaller nodules. In 78 analyses from 47 *RV Sonne* samples, the >8 mm nodules averaged 19.8% P₂O₅ and the 1–8 mm nodules averaged 21.6%. In 63 *RV Valdivia* screened samples >1 mm derived from respective bulk samples, the P₂O₅ average was 22.0%. The large nodules have higher CaO and lower K₂O, SiO₂ and Fe₂O₃ relative to the smaller nodules. The P₂O₅ concentration is reduced in smaller nodules by the glauconite coating and in larger nodules by calcite in the core (Kudrass & Cullen, 1982). The relatively high Fe₂O₃ content of the outer layer of some nodules reflects the presence of goethite in the coating. P₂O₅ and U are slightly concentrated in the transition zone. The contribution of the outer layer to the total volume of the nodules decreases with increasing nodule size. The positive correlation of median nodule diameter with, for example, K₂O concentration is also a reflection of the presence of the coating glauconite. A concentration of 7.54% K₂O (which corresponds to 100% glauconite) results in a theoretical median of 0.25–0.125 mm, which is consistent with the estimated thickness of 0.11 mm for the glauconite coating. The highest P₂O₅ concentrations occur in the 4–8 mm grain size fraction; in the *RV Tangaroa* sample data (Pasho, 1976), this was found to be in the 5–10 mm fraction. The histograms for the number of samples with a particular elemental oxide composition for the *RV Sonne* data are presented in Figure 13-2.

Table 13-1: Average chemical composition (wt%) bulk sample and 1(2)–8 mm and >8 mm size fractions for Chatham Rise phosphorite nodules (Johnston, 2013).

Sample	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	P ₂ O ₅	K ₂ O	SO ₃	F	LOI
Sonne Average	7.82	0.03	1.11	3.48	0.71	43.65	1	20.69	1.04	1.6		17.26
Sonne Avg. >8 mm	3.17	0.02	0.47	2.09	0.41	48.41	0.89	19.84	0.42	1.38		21.27
Sonne Avg. 1–8 mm	12.48	0.04	1.75	4.87	1	38.88	1.11	21.53	1.65	1.83		13.25
DD Average	8.36		0.97	4.45	1	43.86	0.51	19.81	0.83	1.38	2.54	15.89
DD Avg. >8 mm	4.96		0.66	3.2	0.72	47.28	0.44	19.23	0.19	1.35	2.56	18.97
DD Avg. 2–8 mm	11.73		1.29	5.68	1.29	40.47	0.59	20.31	1.46	1.42	2.52	12.92
TI Average	9.38		1.28	4.59	1.03	42.85		19.92	0.89	1.4	2.47	15.13
TI Avg. >8 mm	6.2		1	3.34	0.74	46.12	0.42	19.62	0.37	1.38	2.58	17.61
TI Avg. 2–8 mm	12.56		1.56	5.84	1.32	39.59	.55	20.22	1.42	1.43	2.36	12.64

Note:

1. The QP notes that the geochemical data discussed in this section are not necessarily representative of the mineral resource, and further work is required to establish more accurate phosphate grades for the Chatham Rise deposit.
2. DD – RV Dorado Discovery; TI – MV Tranquil Image

CRP carried out a detailed particle size and chemical analysis on the suite of *RV Dorado Discovery* samples. The process involved a sieve analysis to provide split fractions of the bulk *RV Dorado Discovery* samples into size ranges of 1.18–1.70 mm, 1.7–2.0 mm, 2.0–4.0 mm, 4.0–8.0 mm, 8.0–25.4 mm, and 25.4–80.0 mm. The chemical composition was determined for each fraction by XRF analysis. Figure 13-3 provides a graphical representation of the P₂O₅, CaO, SiO₂, and Fe₂O₃ contents of the *RV Dorado Discovery* samples across the sieve size ranges and follows the trends seen in samples from previous cruises. Johnston (2013) noted that if a particle size cut-off is to be invoked in the mining and processing operation, then as far as P₂O₅ is concerned, the particle size fraction smaller than ~2 mm should be separated and possibly discarded.

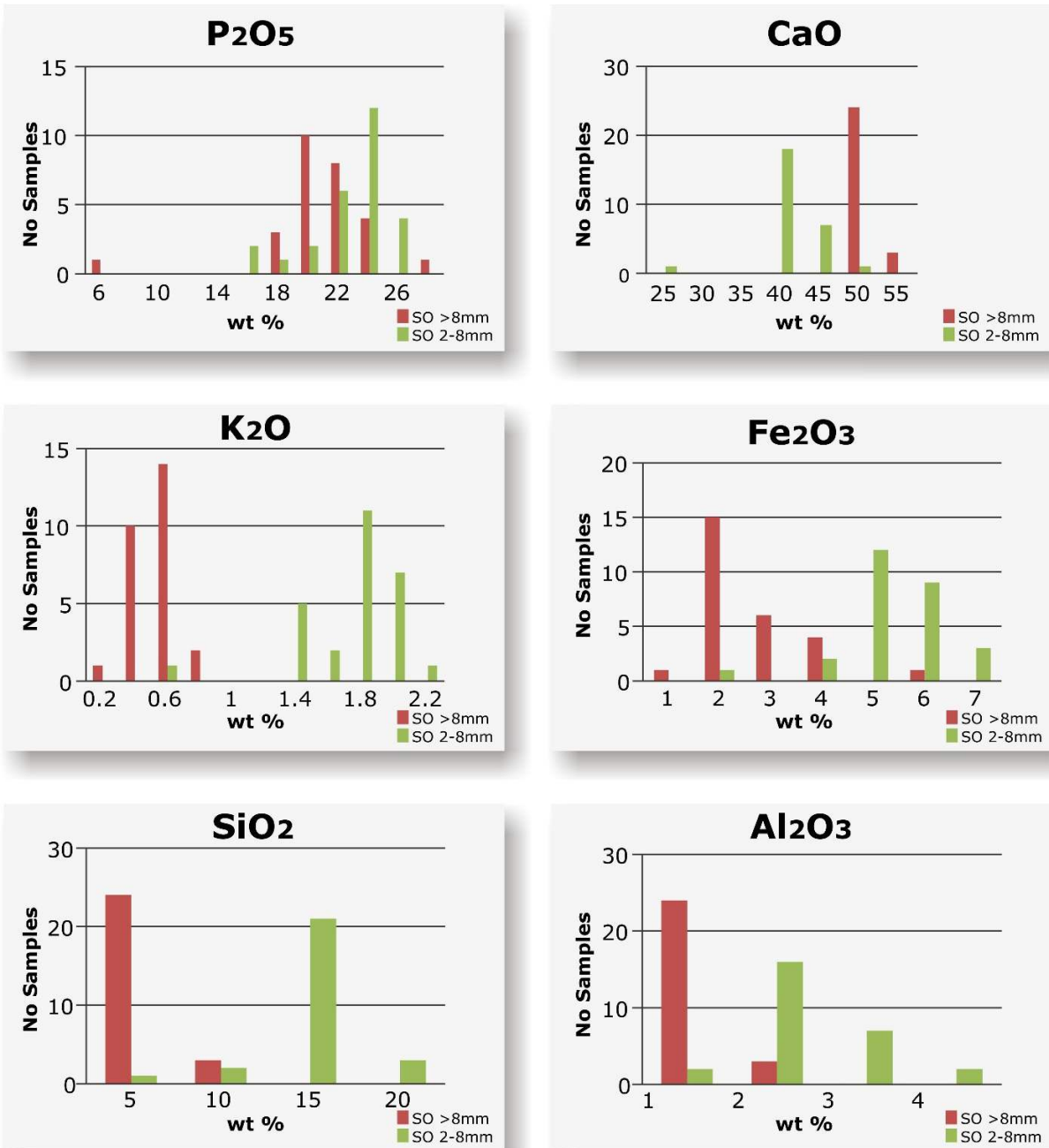


Figure 13-2: Average P₂O₅, CaO, K₂O, Fe₂O₃, and Al₂O₃ contents for each of the respective composition ranges for the 2–8 mm and >8 mm size fractions for the *RV Sonne* samples (Johnston, 2013).

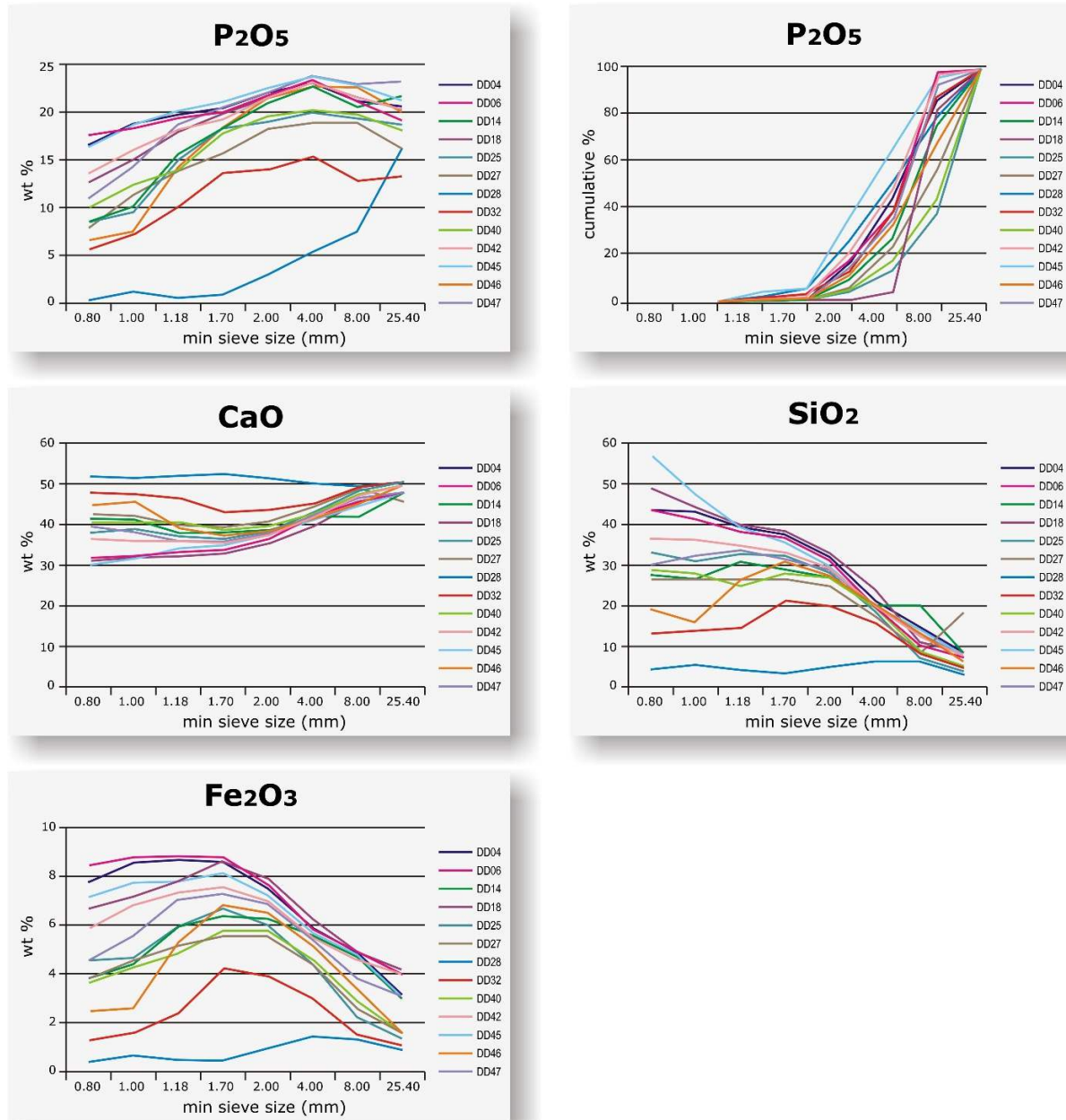


Figure 13-3: P₂O₅, CaO, SiO₂, and Fe₂O₃ contents of sieved *RV Dorado Discovery* samples (Johnston, 2013).

13.4 Trace Elements

Trace element distributions are similar for larger and smaller nodules. Some elements, e.g. Cu, Mo, Ba, Co, and V, are typically evenly distributed in nodules of all sizes, and are thought to be original constituents of the parent limestone. In contrast, Sr, Th, and U occur in higher proportions in nodules measuring 8–64 mm and are presumed to have been introduced during phosphatisation. In nodules <8 mm, the dominant constituents are As, Ni, Pb, Rb, Y, Zn, and Zr, and their introduction may be associated with impregnation by glauconite. Uranium concentrations are elevated, with an average

grade of 216 ppm in the *RV Sonne* samples, and may even attain ore grade with U being extractable during processing that involves solution (Syer et al., 1986; Cullen, 1987). However, even if the phosphorite was used as an unprocessed, direct-application fertiliser, studies suggest there is little risk of U contaminating livestock or building up in the soil (Cullen, 1987).

Tests by Syers et al. (1986) indicate that the phosphorite from the Chatham Rise is very low in Cd (2 mg/kg) and As (below level of detection). This was also the case for the *RV Dorado Discovery* samples, where 13 samples analysed on both coarse and fine fractions did not return Cd levels over the limit of detection (<2 ppm). Sayers also noted elevated Uat 100 mg/kg; however, the QP cannot confirm the source of the phosphorite sample used for this analysis. The analysis of sediment presented in Golder Associates (2013) included the abundance of key environmental trace elements. Elements such as As (about 6 mg/kg in sediment and <4 mg/kg in chalk) and Cd were low (0.2 mg/kg in surface sediment and 0.3 mg/kg in chalk), even though Cd is often associated with phosphorites. Mercury (Hg) abundances were low, at ~0.06 mg/kg in surface sediments and ~0.04 mg/kg in chalk samples.

Further work is needed to assess metallurgical variations between geological facies. Deleterious elements are not considered to be an issue; however, the QP recommends that any future testwork includes systematic analysis of As, Cd, and U.

13.5 Recovery

Boskalis undertook studies for the provision of a separation plant on a ship similar to the *Queen of the Netherlands*. The proposed processing plant would contain four parallel processing streams for the coarse fraction (>8 mm) separation and two to four processing streams for the finer (2–8 mm) fraction separation. The separation concept is illustrated in Figure 13-4.

Most of the sampling data informing the MRE were from grain fractions of >1 mm, whereas the Boskalis' conceptual separation plant studies assumed a >2 mm fraction, with smaller fractions returned to the ocean floor. A small percentage of phosphorite nodules in the 1–2 mm fraction would therefore not be recovered. Limited size fraction analysis (CRL, 2013) suggests that this may account for only ~1% loss of recovery, with a low concentration of P₂O₅ (Johnston, 2013).

The QP notes that the samples used for the mineral processing and metallurgical testing are not necessarily representative of the various types and styles of mineralisation at the Project or the mineral deposit as a whole. However, the QP considers the level of testwork conducted to assess the metallurgical properties of the Chatham Rise Phosphorite deposit to provide sufficient confidence for the classification of an Inferred Mineral Resource.

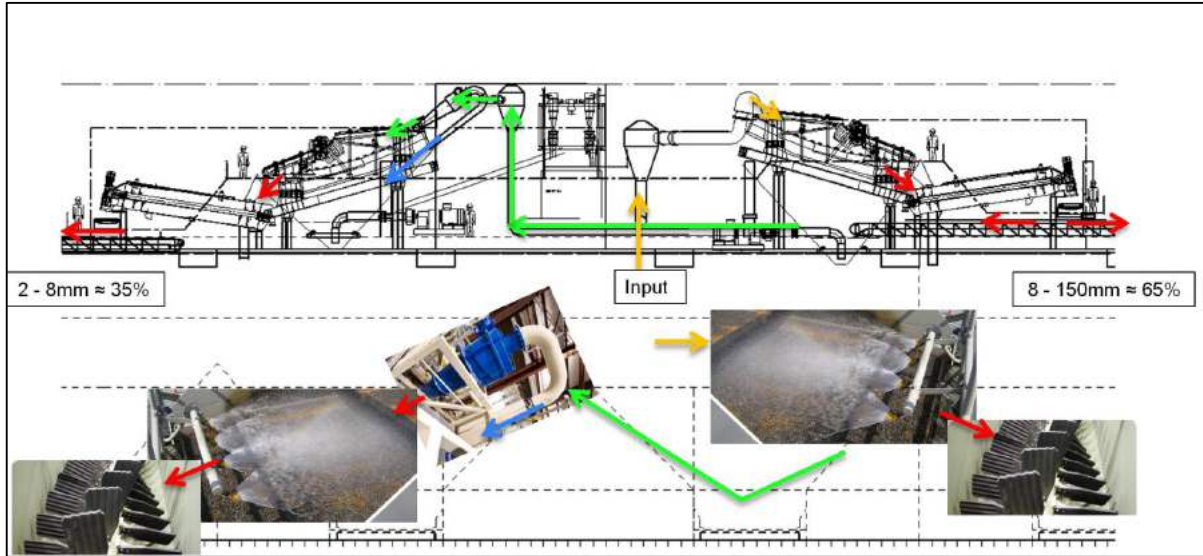


Figure 13-4: Separation process proposed by Boskalis for the *Queen of the Netherlands* (Boskalis, 2013).



14. Mineral Resource Estimates

14.1 Informing Data

14.1.1 Data Handling

The data on which the mineral resource estimate (MRE) is based are stored in a Microsoft Access database. Because of the simplicity of the data structure (i.e. a single table with two-dimensional points and grade data and no related or inter-dependent tables or other data sheets), the QP considers this data storage solution is adequate. Microsoft Access database update extracts would be prefixed with a date tag to denote the date of the database (YYMMDD) to allow proper version control, both throughout the CRP exploration programmes as well as the database validation and upgrade process as part of the estimation process. The database was stored on a cloud-based storage system that allows full audit trail and stores a back-up of each new version of the database. Data for estimation were extracted from this database into a single flat Microsoft Excel table.

During the CRP exploration work, the database was managed and administrated by employees of Kenex Knowledge Systems Ltd (GIS specialists).

A new Mineral Resource has been estimated as part of the Report using mostly historical data validated and verified by the QP. Since the Mineral Resource is based predominantly on historical data, a process was set up to ensure only validated and verified data were included in the mineral resource estimate. Any data that could not be validated or verified were flagged or a comment added so that the data could be excluded (see Section 11.4 for a more comprehensive discussion).

It is important to note that even though many data issues were resolved through the validation process, several issues remain which simply cannot be resolved. Several assumptions were required to calculate final phosphorite grades for some samples and these samples have been appropriately flagged and downgraded in the database. This has been considered in the estimation process where relevant, and has been taken into account when classifying the resource.

14.2 Interpretation & Model Definition

14.2.1 Geological Domains

Wireframes were created for ten different seismic facies to sub-domain the sample data sensibly and create appropriate domains for grade estimation. However, given the large overall size of the area covered by the sampling campaigns, and the relatively low resolution of the geological data within these large areas, the domains can only be considered applicable to the large-scale variability of the data. It is not possible to define smaller-scale features like individual iceberg furrows into domains at this stage. Thus, even though geological understanding of the process is considered sound, the resolution of the data does not allow optimum application of this knowledge. This has been considered when classifying the Mineral Resource.

The specific geological controls on mineralisation are discussed in Section 7.

14.2.2 Estimation Domains

Beyond the constraint by geological domains, the MRE was not constrained by estimation domains. Extrapolation of grades into blocks was therefore simply controlled by the size of the search ellipse, which was kept at short dimensions, based on spatial analysis of the sample data.

14.2.3 Extrapolation

Extrapolation of data into poorly sampled areas was minimised.

14.2.4 Alternative Interpretations

Given the low resolution of the available wireframes for geological domains, it is possible to generate alternative interpretations for the geology. Given the level of confidence at which the MRE is classified (see Section 14.12), it is not expected that alternative interpretations would have a major impact on either Mineral Resource classification or grade estimation.

14.2.5 Coding & Definition of Domains

Using the seismic facies domains described above, the sample data were coded into the ten different domains defined during the seismic mapping (Figure 7-4). The data were further coded with a sample quality ranking (SQR) to investigate the effects of including lower-quality data into the resource. Details of the SQR have been discussed in Section 11.4. The SQR attribute has a large impact on the final resource figures. There are many different categories and factors influencing the quality of the sample. An SQR value of 4 was used as a cut-off for the estimation process to ensure that only suitable samples were included in the analysis.

Several checks were carried out to make sure that samples were correctly coded and to determine whether any samples were missed in the coding process.

14.2.6 Sample Support

Sample support varies between the various sampling cruises and is considered a weakness of the available sample data. The sample taken on the *RV Sonne* cruise was about eight times larger than on the *RV Valdivia* and *MV Tranquil Image* cruises. This means there is relatively large sample variance within the *RV Valdivia* and *MV Tranquil Image* datasets, although this is somewhat moderated by the consistency of the mineralisation.

Some of the smaller samples have been allowed into the estimation process, but they are limited to an SQR of 3–4 and are subsequently also downgraded at the classification stage based on a high required minimum amount of informing samples. In essence, high variance can be offset by an increase in sample numbers to still produce a reasonable estimate.

14.3 Summary Statistics & Data Preparation

Data for each of the ten sub-domains were statistically analysed (Figure 7-4). Main points assessed were the number of data points, mean, variance, covariance, histogram, cumulative frequency, and mean/variance vs top-cut. This was done at an SQR top cut of 4. The sample data statistics are summarised in Table 14-1.

Table 14-1: Basic statistics for sample data for each domain (capped at SQR of 4).

	No. of Samples	Mean Grade (Ph kg/m ³)	Grade CV (Ph kg/m ³)	Mean Depth (m)	Mean SQR
Domain 1	1	13		0.38	4.0
Domain 2	0				
Domain 3	30	197	1.4	0.21	3.3
Domain 4	482	289	1.0	0.21	2.5
Domain 5	12	375	1.4	0.21	3.2
Domain 6	14	50	1.7	0.28	4.0
Domain 7	23	57	1.4	0.29	4.0
Domain 8	6	208	2.1	0.25	4.0
Domain 9	121	239	1.6	0.23	2.2
Domain 10	6	125	0.7	0.14	1.8
Total (Mean)	695	172	1.4	0.24	3.2

CV – coefficient of variation

The sample points for the *RV Valdivia* and *RV Sonne* cruises overlap in the central area and this allows statistical comparison between the datasets in this area. For each sample of the *RV Valdivia* dataset, any points within the *RV Sonne* dataset that fell within a radius of 400 m were flagged. For each *RV Valdivia* point there could be more than one *RV Sonne* point within the radius, and vice versa. The process was capped at a quality ranking of 4 to only allow relatively good samples to be compared. This resulted in 13 *RV Valdivia* points and 23 *RV Sonne* points (green triangles and green circles, respectively, in Figure 14-1) for comparison. The averages for the two datasets are 313 Ph kg/m³ (*RV Valdivia*) and 298 Ph kg/m³ (*RV Sonne*) data. These are considered reasonable results and a positive indication that the *RV Valdivia* data can be used together with the *RV Sonne* data in the model.

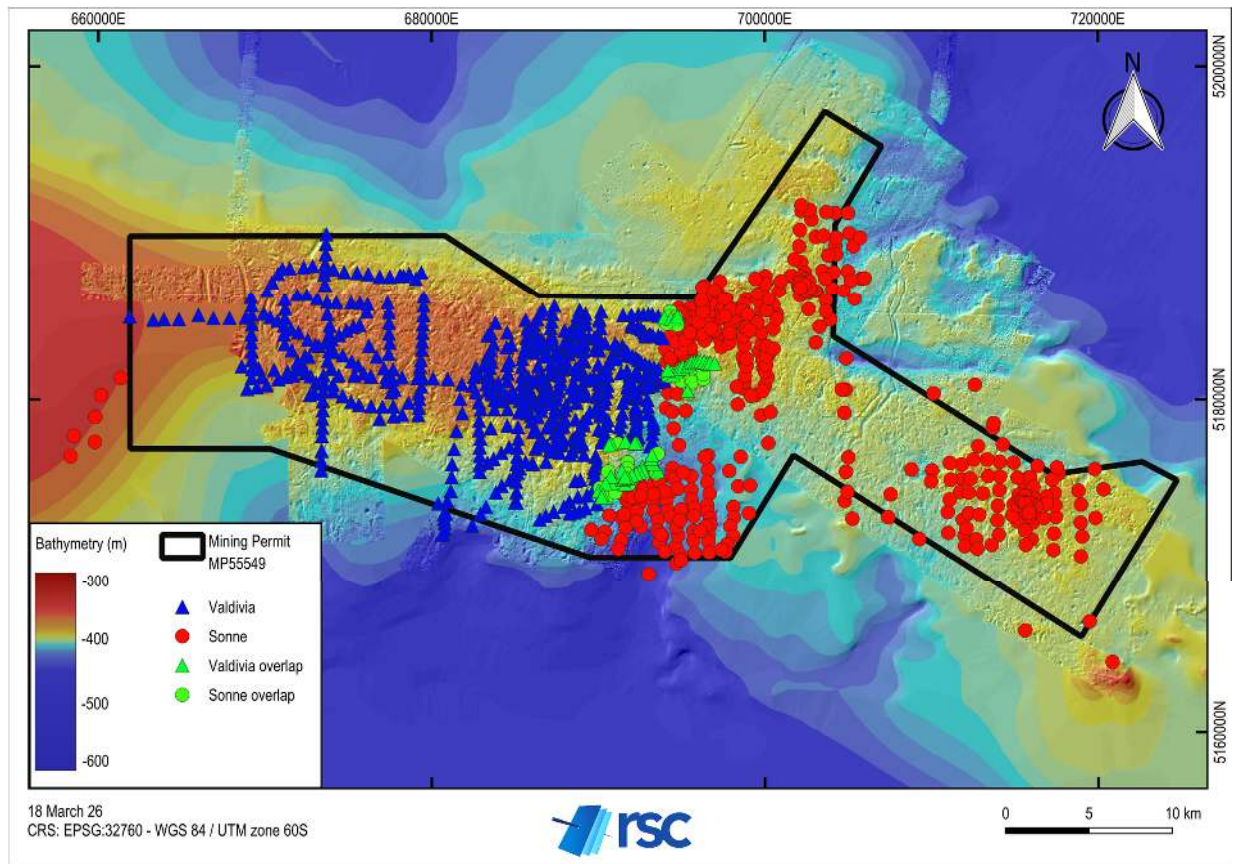


Figure 14-1: Sample overlap (green) between *RV Sonne* (red circles) and *RV Valdivia* (blue triangles) cruises.

14.4 Grade Capping

Investigation of cumulative frequency, histograms, and mean/variance vs top-cut plots indicated that top-cutting was warranted for the distribution in domain 9. A grade cap of 150 Ph kg/m² was chosen which caps two outlier samples to this value and lowers the mean of the domain from 35 Ph kg/m² to 32 Ph kg/m². The depth was not capped as it was limited to the depth of the sampling tool used.

14.5 Spatial Analysis & Variography

Geological knowledge is the best guide to define directions of grade continuity. However, for this analysis the grade continuity cannot be determined. A simple visual thematic representation of the grades within each of the established geological domains in plan view does not indicate any consistent or coherent trends or directions. Two-dimensional directional variography confirms this, with several short-range directions of increased coherence, mixed within each of the ten domains. This may indicate a lack of high-resolution geological control on the mineralisation and that further sub-domaining is required. However, this is not currently possible. This result has been considered when classifying the Mineral Resource.

For this reason, an isotropic search is adopted on each domain. An omni-directional normal scores variogram was constructed on facies domains 4 and 9 as well as the entire dataset, and capped at an SQR of 4, to investigate the nugget effect and the variogram ranges as input parameters for the 2D Ordinary Kriging estimation process. Nested spherical structures were used in normal scores transform to deal with the skewed dataset. Data were declustered and top-cut before processing for smoother results. The result is presented in Figure 14-2.

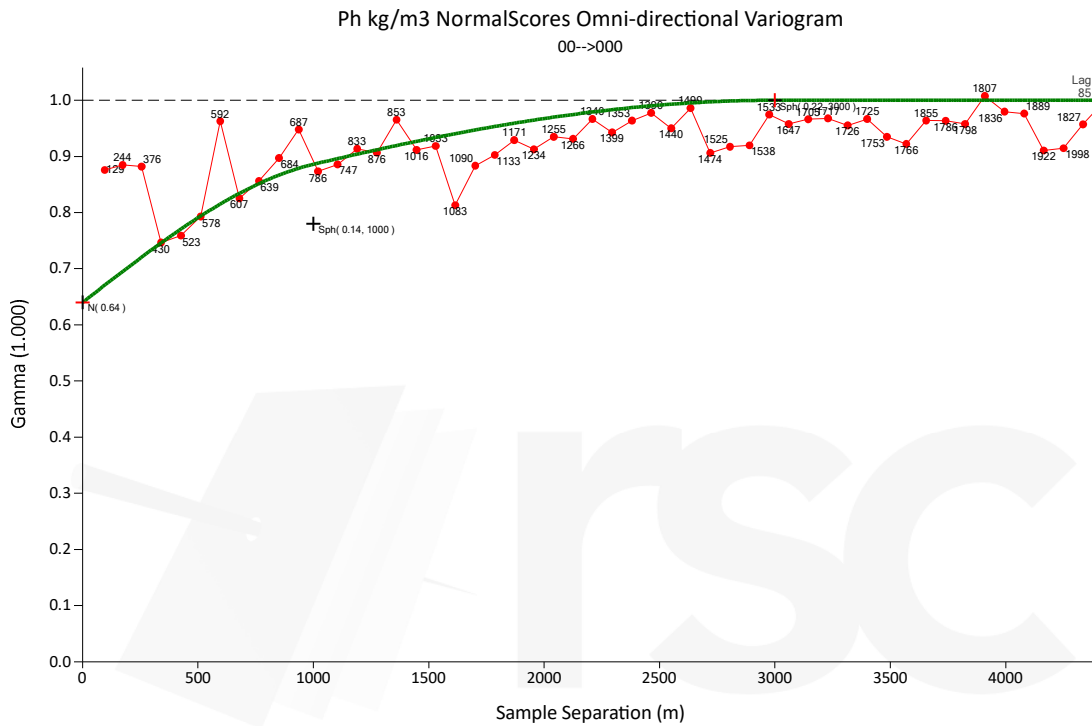


Figure 14-2: Omni-directional variogram for the entire dataset, capped at a quality ranking of 4 indicates a high nugget of 65%, a short-range structure at around 1,000 m and 80% of the variance, with an overall range of around 3,000 m (using a lag of 85 m).

14.6 Block Model

A block model was constructed that covers the main sampled area. A block size of 1 km × 1 km × 1 m was chosen, based on the average data spacing in the main sample areas, in an attempt to maintain a balance between the sparsely sampled and densely sampled areas. The model was brought into two dimensions (only one block in the z-direction) and all the samples given an elevation of 0.5 m RL.

Attributes were assigned for depth, grade, nodule abundance, Mineral Resource class and SQR.

Table 14-2: Block model description.

Parameter	X	Y	Z
Parent Block Size (m)	1000	1000	1000
Base Point Coordinates (corner)	655000	5140000	1
Size (m)	128000	60000	1
Size (blocks)	128	60	1
Azimuth(°)	0		
Dip(°)	0		
Pitch (°)	0		

14.7 Search Neighbourhood Parameters

A isotropic search was applied, with a maximum search distance of 3,000 m. The minimum number of samples was set at 2 to allow sparsely sampled areas to be estimated (to also estimate the exploration potential outside the main mineral resource). The maximum number of samples was set at 30.

14.8 Estimation

Estimation was performed using 2D accumulation Ordinary Kriging on the parameters Ph kg/m² (i.e. grade × Depth), Depth and SQR. The 2D accumulation estimation is considered appropriate because there is a negative correlation between thickness and grade, and variability in the vertical direction is disregarded as selective mining is not possible (Figure 14-3). Each of the domains was estimated in isolation, i.e. neighbouring data from other seismic facies domains were excluded from the estimation process. Each block therefore ended up with estimated values for Ph kg/m², Depth and SQR. The grade (Ph kg/m³) was then calculated by dividing Ph kg/m² by the estimated Depth for each block.

Phosphorite wet density was measured from nodules collected during the *RV Valdivia* (1978) and *RV Sonne* (1981) cruises. However, estimation of density was not required for the estimation of wet tonnages, which are obtained from the direct estimation of nodule abundance (Ph kg/m²).

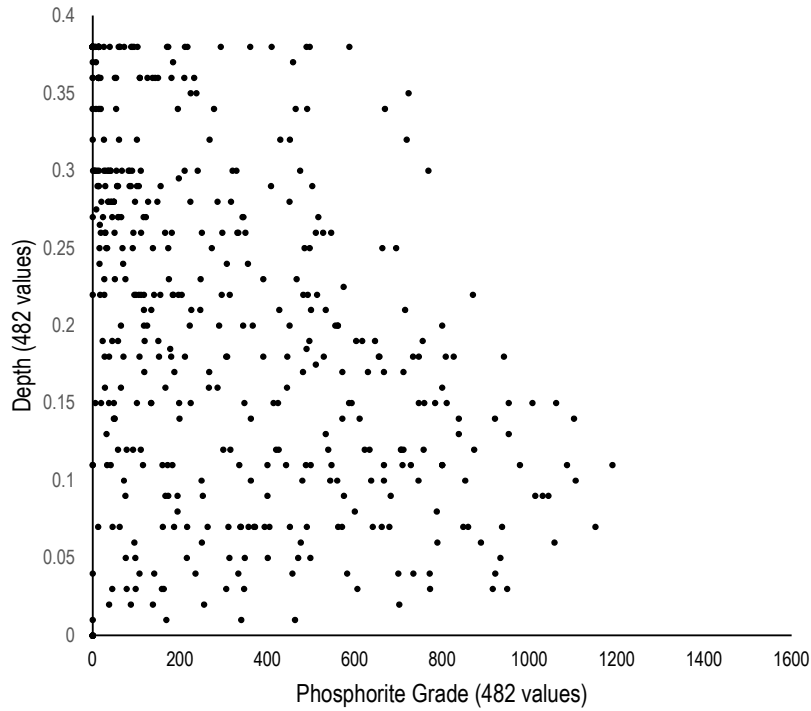


Figure 14-3: Correlation between depth (m) and grade (Ph kg/m³) for domain 4 (482 points) indicating negative correlation, however, a few of the highest-grade samples appear to be related to the shallower depths.

14.9 Validation

The block model was checked for representativeness by comparing the raw data with the block data for each domain (Figure 14-4). This demonstrated several instances in a densely sampled area where a zero-grade sample surrounded by several high-grade samples. This high local variability is also clear from the variogram (Figure 14-2).

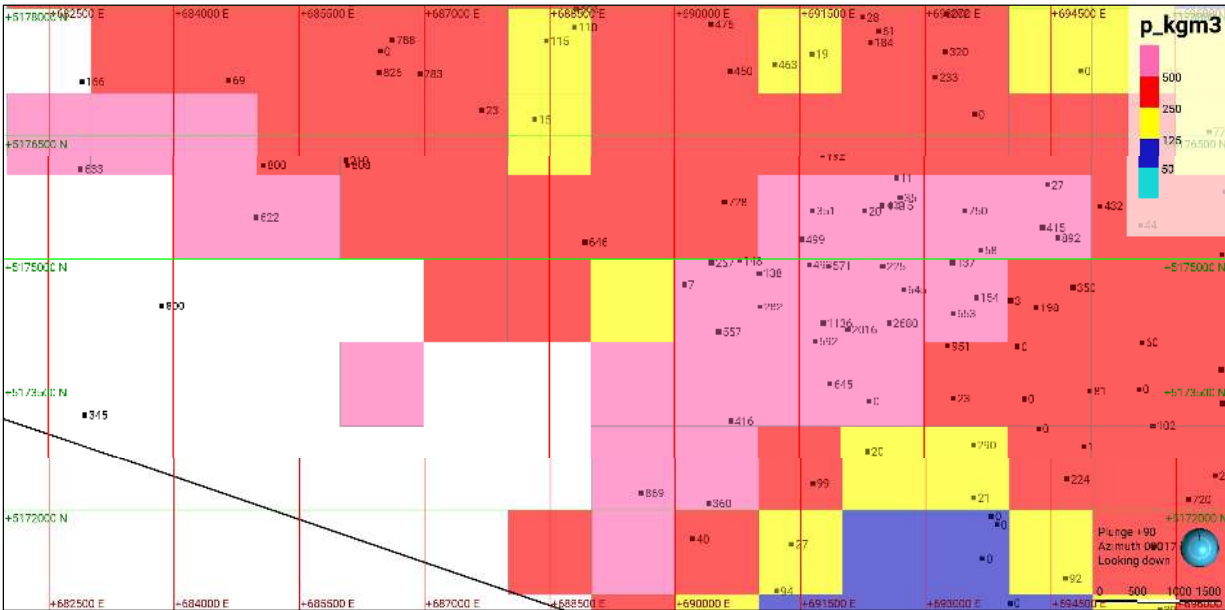


Figure 14-4: Visual validation of block grades vs sample grades. Only blocks considered for the Mineral Resource are presented. Cyan <math>< 50 \text{ Ph kg/m}^3</math>, Blue <math>< 125 \text{ Ph kg/m}^3</math>, Yellow <math>< 250 \text{ Ph kg/m}^3</math>, Red <math>< 500 \text{ Ph kg/m}^3</math> and Magenta >500 Ph kg/m³.

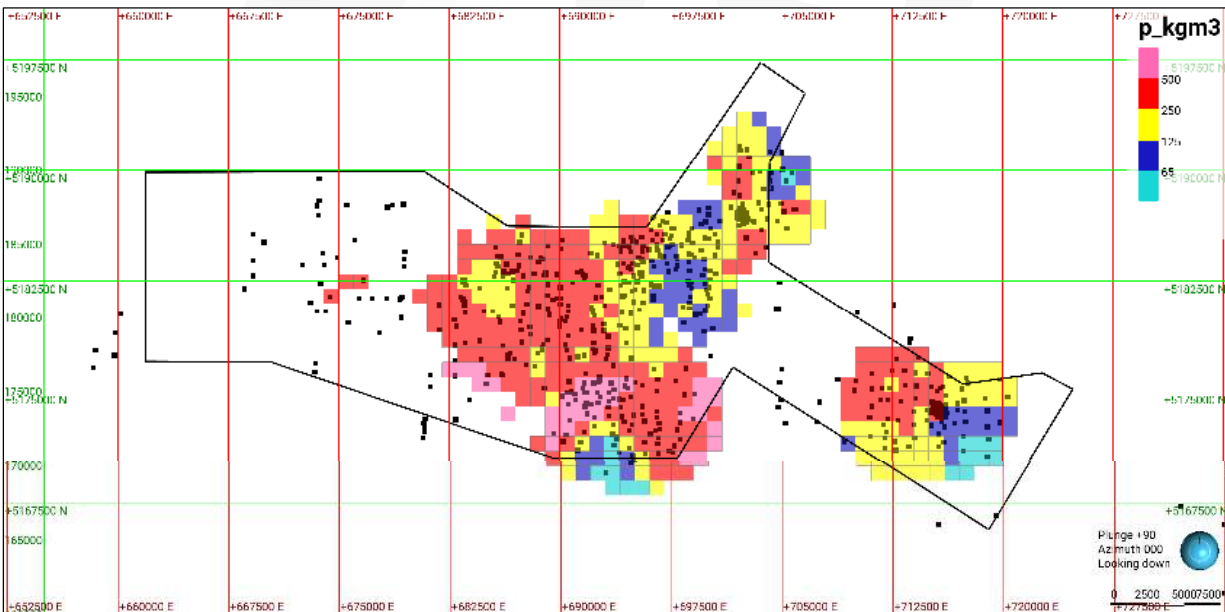


Figure 14-5: Estimation results illustrating block grades. Cyan <math>< 65 \text{ Ph kg/m}^3</math>, Blue <math>< 125 \text{ Ph kg/m}^3</math>, Yellow <math>< 250 \text{ Ph kg/m}^3</math>, Red <math>< 500 \text{ Ph kg/m}^3</math> and Magenta >500 Ph kg/m³. The Mining Lease boundary is indicated by the black outline.

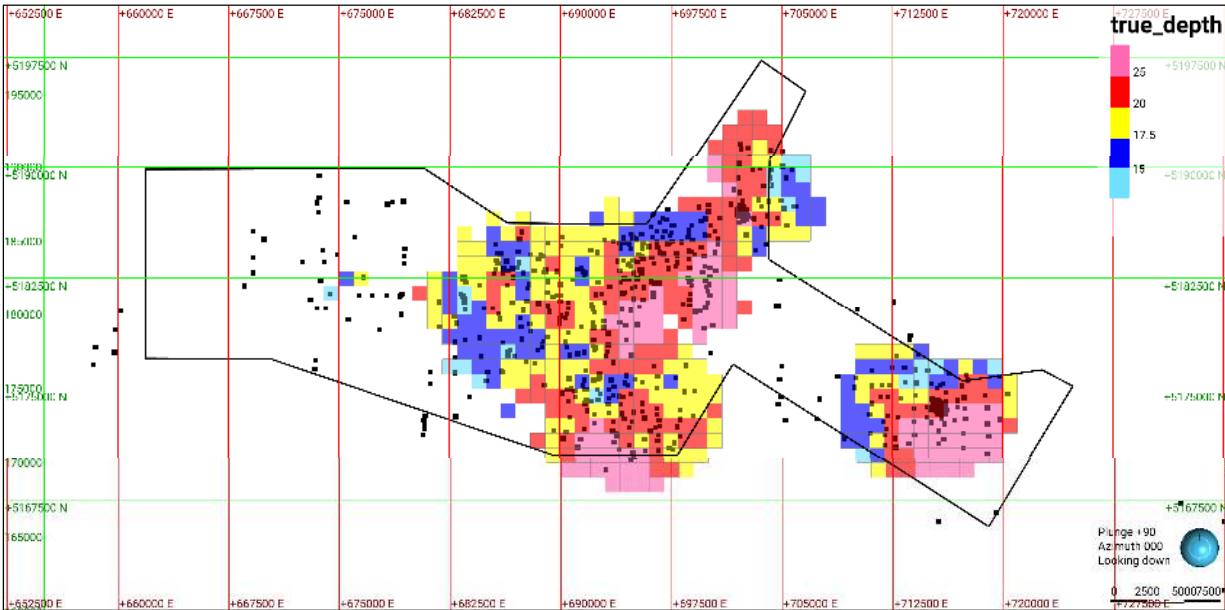


Figure 14-6: Estimation results illustrating true depths. Cyan <15 cm, Blue <17.5 cm, Yellow <20 cm, Red <25 cm and Magenta >25 cm. The Mining Lease boundary is indicated by the black outline.

A trend analysis in the east direction (Figure 14-7) indicates that the resource blocks represent the sample grades well. Only for the section between 70,4000E and 71,4000E do the samples have a higher average grade than the blocks but this area is poorly informed (low number of samples).

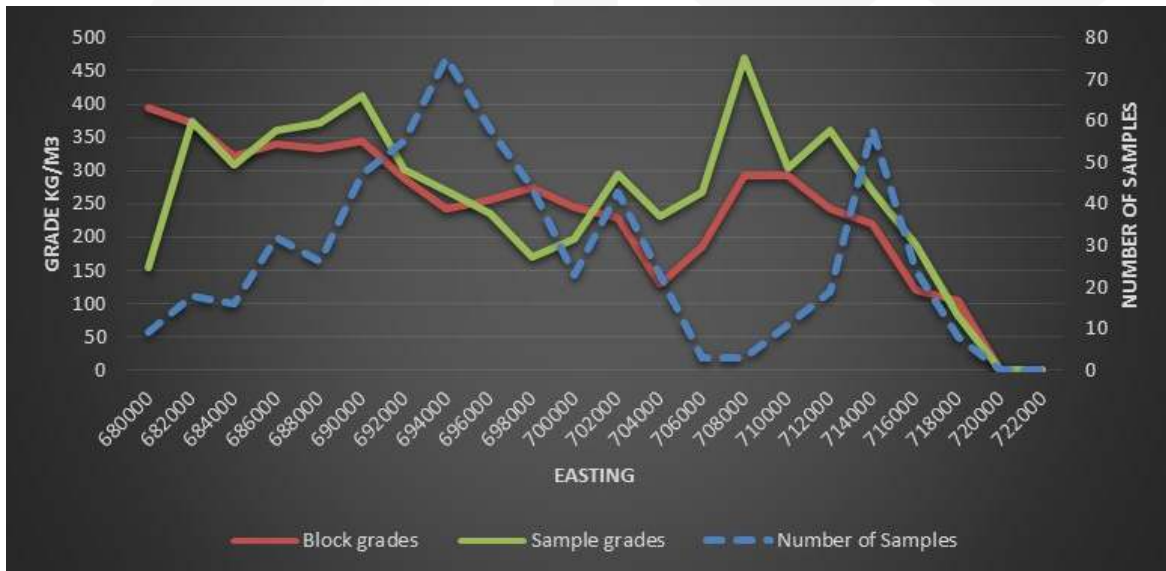


Figure 14-7: Trend analysis demonstrating validation of block grades vs the input samples from west to east (left to right).

14.10 Sensitivity Testing

A sensitivity analysis was conducted on the estimation quality varying the minimum number of samples for each block and reviewing the Slope of Regression (SoR), kriging efficiency (Ke) and number of samples per estimate (NS) (Figure 14-8), with higher numbers indicating a higher quality estimate. For material classified as inferred the SoR is 0.6, average minimum number of samples is 20 and Ke is 0.1, which in the QP’s opinion supports the classification of Inferred Mineral Resources.

The characterisation of estimation confidence subsequently used in the classification of Inferred Mineral Resources is based on the following criteria.

1. The minimum number of informing samples for each block was set to 10 to make sure that there were sufficient samples to inform each block falling into the Inferred classification category.
2. Blocks with lower minimum number of informing samples were allowed into the Inferred classification if the SQR for the block was lower than 3 (indicating good quality samples informed the block) as long as the minimum informing samples was still at least 5.

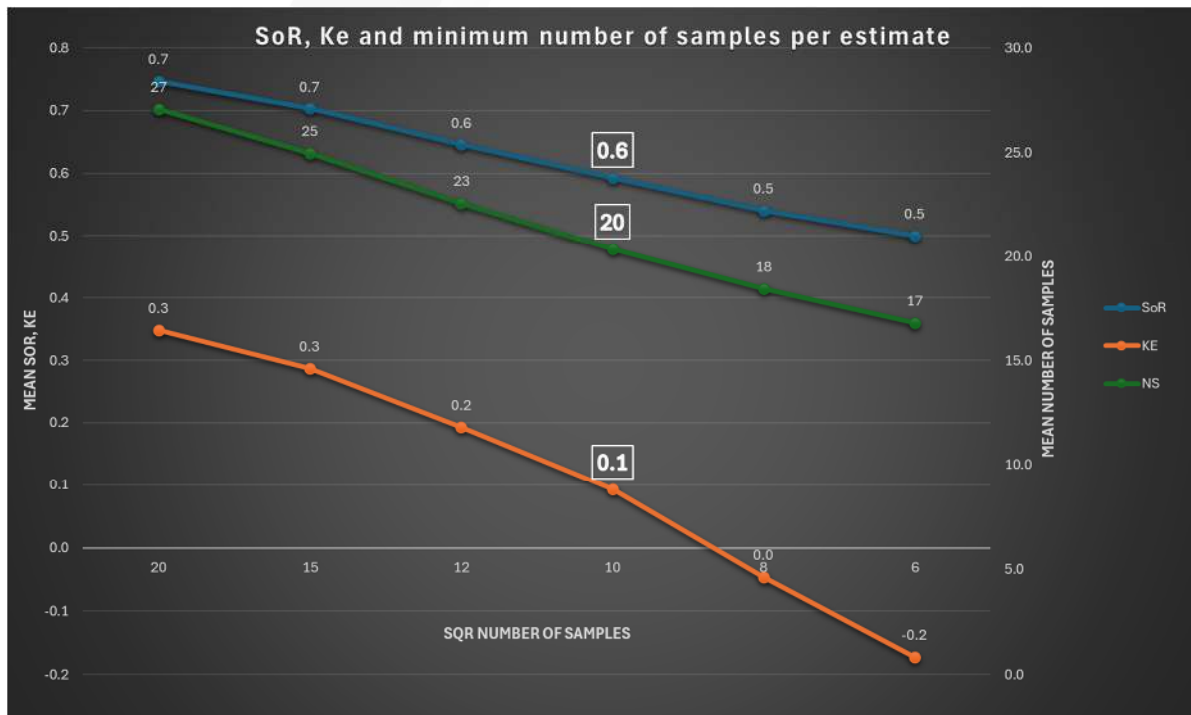


Figure 14-8: Sensitivity analysis comparing estimation quality.

14.11 Depletion

There has been no known mining of the Project; therefore no depletion was applied.

14.12 Classification

The QP has classified the MRE in the Inferred Mineral Resource category, in accordance with NI 43-101 and the *CIM Definition Standards on Mineral Resources and Mineral Reserves* (Canadian Institute of Mining, Metallurgy, and Petroleum, May 2014). For the Inferred Mineral Resources, geological evidence is sufficient to imply but not verify geological and grade continuity. The MRE is based on exploration, sampling, and geochemical analysis information gathered through appropriate techniques.

It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration. For the Inferred resource portion of the MRE, confidence in the estimate is not sufficient to allow the results of the application of technical and economic parameters to be used for detailed planning in pre-feasibility or feasibility studies. Caution should be exercised if Inferred Mineral Resources are used to support technical and economic studies such as a scoping study or preliminary economic assessment.

14.12.1 Classification

Given the considerations for eventual potential economic extraction, the QP reports a MRE of 71,000,000 m³ at an average grade of 295 Ph kg/m³, within MP 55549. The Mineral Resource is classified as an Inferred Mineral Resource at a cut-off grade of 100 Ph kg/m³ for a total contained 21.1 Mt of phosphorite (see Table 14-3). There are no Mineral Resources classified in the Indicated or Measured categories. As the Chatham Rise phosphorite resource is classified entirely as an Inferred Mineral Resource, it does not constitute a Mineral Reserve and so does not have demonstrated economic viability. The specification of the phosphorite (i.e. the phosphate content) has been discussed in Section 7.3 and Section 13.3 of the Report. The average concentration of the specification is in the order of 18–19% P₂O₅ of screened material. The average thickness of the Mineral Resource is 0.20 m. The grade-tonnage relationship is presented in Figure 14-9.

Table 14-3: Statement of Mineral Resources (Phosphorite) for MP 55549, Chatham Rise with an effective date of 29 April 2026.

Classification	Volume (m ³)	Thickness (cm)	Grade (Ph kg/m ³)	Contained Ph (Mt)
Inferred	71,000,000	20	295	21.1

Notes:

1. The Mineral Resource is reported in accordance with CIM Definition Standards for Mineral Resources and Mineral Reserves (May 2014).
2. The MRE has an effective date of 29 April 2026.
3. The Mineral Resource is contained within MP 55549.
4. Estimates are rounded to reflect the level of confidence in these resources at the present time. All resources have been rounded to the nearest 0.1 million tonnes.
5. Grade (Ph kg/m³) is the weight of phosphorite per cubic metre.
6. Contained Ph Mt is contained weight of phosphorite per million tonnes.
7. The average concentration of the specification is in the order of 18–19% P₂O₅ of screened material.
8. The Mineral Resource is reported at 100 kg/m³ phosphorite cut-off grade, calculated using a phosphate rock price of USD 150 per tonne based on prices from 2024 to 2026.
9. The Mineral Resource is classified entirely as Inferred. It does not constitute a Mineral Reserve and so does not have demonstrated economic viability.

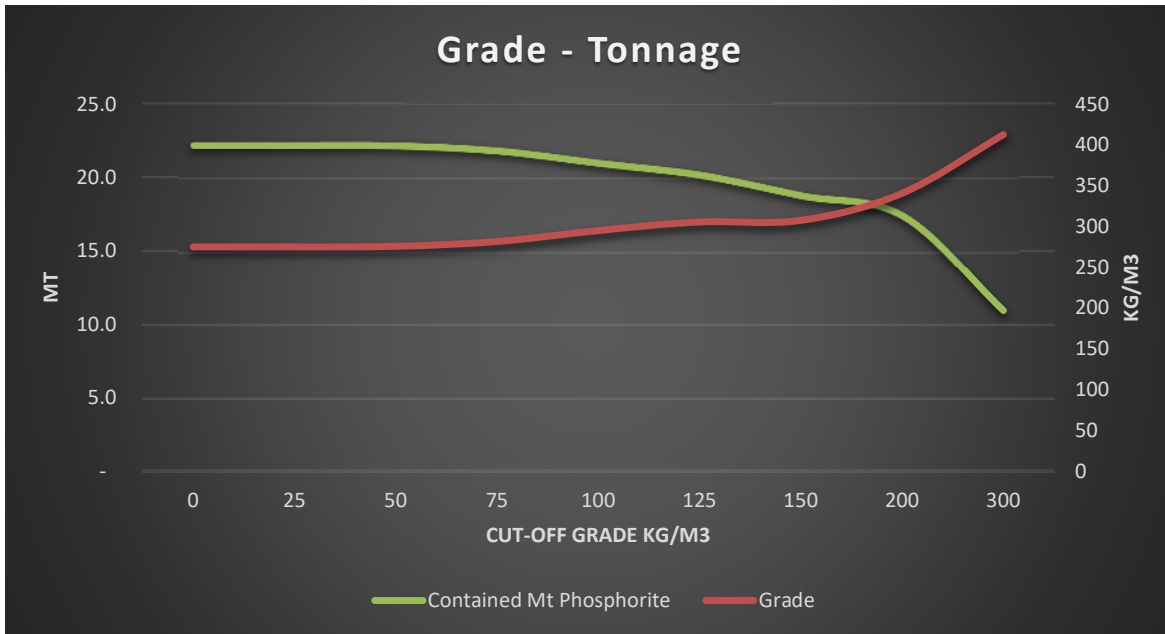


Figure 14-9: Relationship between cut-off grade (horizontal axis) and contained phosphorite (left axis) and resource grade (right axis).

This classification adequately reflects the QP's view of the deposit and is based on several factors, in order of importance.

1. The QP's analysis indicates that a potentially economically extractable phosphorite mineral resource exists in the Project area. Several high-profile sampling cruises, most independent from each other, have all identified grades of economic interest within the same area. These cruises have been well documented and specific knowledge on sampling systems has been retained and included in the Report.
2. The overall amount of sampling within the mineral resource area is abundant, and, within each cruise domain, there are data points for other cruises that, to various degrees of acceptance, confirm the tenor of mineralisation. There may well be comments to add to the quality of some of the sampling, but these two first points warrant a classification of at least a part of the deposit into the Inferred category.
3. Completion of further environmental studies, in conjunction with potential changes to the EEZ regulations and the approval process may lead to approval of a revised Marine Consent application by CRP.
4. Under *CIM Definition Standards for Mineral Resources and Mineral Reserves* (CIM, 2014), an Inferred Mineral Resource is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. In the QP's opinion, this is an adequate description of the Mineral Resource reported in the Report.

In terms of the boundary between the material that can be classified as an exploration target and what can be classified as Inferred Mineral Resource, the QP notes the following.

1. Blocks were classified primarily on the minimum number of informing samples for each block, which was set to 10 to make sure that there were sufficient samples to inform each block.

2. Blocks with lower minimum number of informing samples were allowed into the Inferred classification if the SQR for the block was lower than 3 (indicating good quality samples informed the block) as long as the minimum was still at least 5 informing samples.

In this way, the QP has incorporated the summary of all the issues that negatively affect the sample quality (i.e. sample location, sample size, sample integrity, etc.) into the SQR value for each block.

14.12.2 Cut-Off Grade

The Mineral Resource is classified as an Inferred Mineral Resource at a cut-off grade of 100 Ph kg/m³ for a total contained 23.4 Mt of phosphorite. Selection of the cut-off grade was based on consideration of assumed mining parameters with respect to meeting the criterion of having reasonable prospects for eventual economic extraction (see comments in section 13).

The Competent Person notes that applying a cut-off grade of 100 Ph kg/m³ results in an average Ph grade for the MRE of 290 kg/m³ and notes that a blending mining programme could be used to satisfy higher production targets by mining both low and high grades. In that context, the Competent Person considers that a cut-off grade of 100 Ph kg/m³ would be reasonable.

14.12.3 RPEEE

No similar deposits exist that are currently in production from which economic parameters can be derived to evaluate the potential of economic extractability. CRP has assessed several mining, economic and environmental concepts, and the QP deems these concepts important for determining whether the Mineral Resource detailed in the Report is 'potentially economically extractable'. However, while the concepts outlined and described below reflect the status of work completed, it in no way can be considered to represent a Preliminary Economic Assessment (PEA) and should not be considered as a reflection of the outcome of a PEA.

In December 2010, CRP invited OceanfLORE, Jan de Nul, van Oord and Boskalis to submit independent studies for the design of a system to recover rock phosphate from the Chatham Rise seabed. Three of the four companies submitted designs that met the required cost parameters (USD 100/tonne or then Euros 70/tonne) and after a rigorous independent evaluation by CRP, Boskalis was selected by CRP in mid-2011 as its preferred technical partner.

CRP and Boskalis worked in collaboration to design a mining vessel to meet the specific requirements of the Project (Figure 14-10). The current design assumes the modification of a dredging vessel. Phosphorite nodules and surrounding material would be retrieved from the seabed using the principles of a conventional trailing suction hopper dredger or drag-head. This material would be brought to the surface via a riser and processed on-board the mining vessel; the phosphorite nodules (>2 mm) being retained and stored on the vessel and the tailings returned to the seabed via a sinker and diffuser (Figure 14-11). When the vessel's holds are full, the mining vessel would stop mining and proceed to a port where the phosphorite nodules would be unloaded, stored and distributed to the market.



Figure 14-10: *Queen of the Netherlands*, an example of a Boskalis vessel that could be significantly modified for mining (CRP, 2012).

The proposed drag-head was designed to efficiently collect phosphorite nodules from a layer that varies in thickness from 0–50 cm, 35 cm on average, and to avoid dredging the underlying chalk/ooze layer. Where the phosphorite-bearing sediment is thicker than 50 cm, the drag-head would not be able to mine the entire layer and would therefore leave some of the nodules behind.

Under the conceptual mining system, the seabed sediment goes up through the drag-head and riser, is processed on the mining vessel, and the non-phosphorite sediments are returned to the seabed through the sinker and diffuser (Boskalis, 2013).

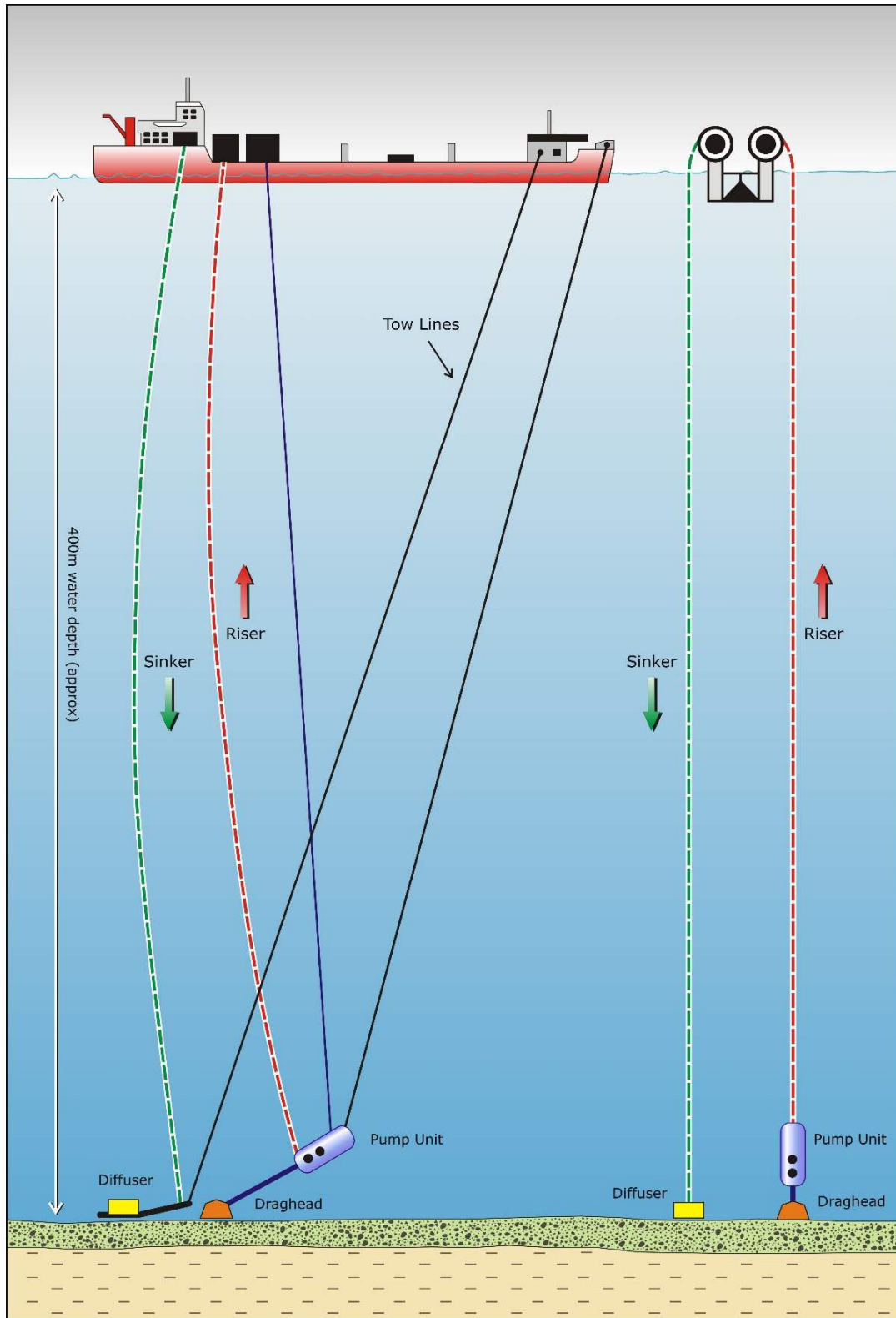


Figure 14-11: Mining system concept (Boskalis, 2013).

The drag-head design was extensively studied by Boskalis (Figure 14-12).

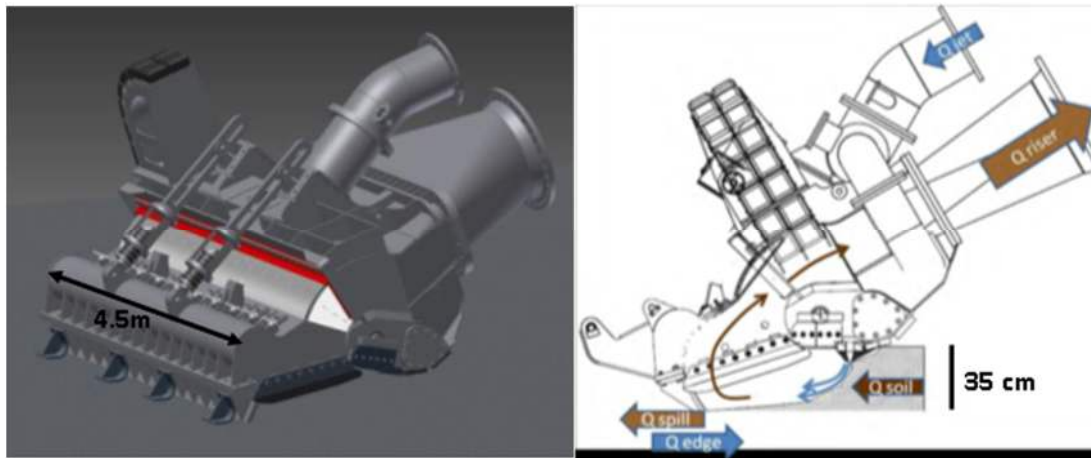


Figure 14-12: Conventional drag-head concept. The drag-head moves to the right in this illustration. Water jets fluidise the seabed sediment (blue arrows) and pumps lift the sediment and water mixture to the riser and onto the mining vessel (brown arrows, Q_{riser}). Q = water flow rate (Boskalis, 2013).

Under this scenario, CRP would mine 1.5 Mt or more of nodules per annum by mining about three 10 km² mining blocks. The mine areas would initially target areas of high resource value and therefore will be spaced throughout the Mining Permit area. As mining plans are still conceptual and the Project has not yet been the subject of any feasibility studies, there are no detailed estimates of expected mining recovery, spillage (ore loss) and dilution.

The core elements of the proposed seabed mining activity may include:

- mining to occur in 350–450 m of water on the Chatham Rise;
- mining an area of ~30 km² each year;
- the trailing drag-arm carrying the suction head is suspended from the vessel by wires (dependent on the mining vessel used, this could either be off one side of the vessel or from the centre of the stern);
- the trailing suction drag-head would excavate up to 0.5 m and, on average, the top 0.35 m of seabed;
- pumping of mined sediment through a riser to the surface vessel;
- on-board processing (physical processes only) of the recovered material to separate and retain phosphorite nodules larger than 2 mm in the vessel's hold/s;
- no overflow of sediment/tailings at the sea surface; and
- controlled disposal of unwanted sediment/tailings onto the seabed and within previously mined areas, through a sinker located on the opposite side of the vessel from the drag-arm.

To optimise the conceptual mining process and use of the mining area, Boskalis proposed a conceptual mining plan. Key factors influencing the consideration of the seabed mining patterns were the dominant wave direction, width that would be covered with tailings, and the vessel's turning time.

Boskalis used satellite-based wave data on the Chatham Rise to model how its vessels would be affected by the wave conditions at the Chatham Rise. Boskalis determined that certain vessels could mine in swells up to 4.5 m, that the vessels could therefore operate ~85% of the time, and that the optimal mining orientation was in a north-northeast direction.

With the currently envisaged layout of the dredging vessel, the material would be loaded on the starboard side, and the tailings (sand and fines) would be discharged on the port side. The path of the vessel would likely be a rough oval (Figure 14-13). A zone of ~250 m wide in the centre of each mining block will be unmined. Of that 250-m zone, 100 m will be covered by tailings from the primary dredge swathes, leaving a centre part of each area neither mined nor covered by a thick layer of tailings. It is expected that this central zone may allow benthic organisms to re-populate rapidly in mined areas after operations in an area have been completed.

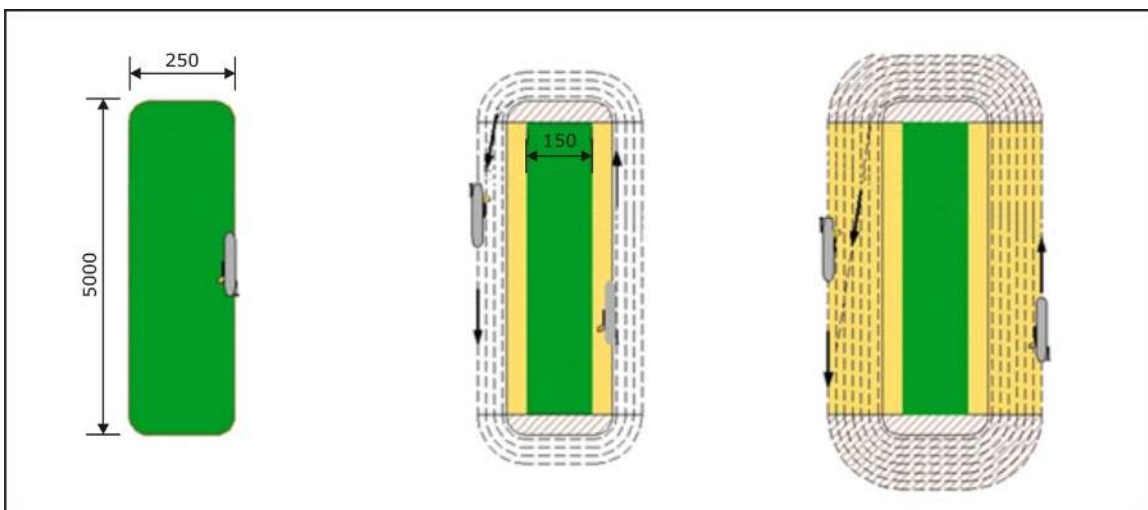


Figure 14-13: Seabed mining trajectory concept (CRP, 2012).

The current mining concepts anticipate using one vessel with a mining cycle of eight days but allowing up to 12 days to accommodate for weather delays and equipment servicing. Each mining cycle would include approximately one day to reach the proposed mining blocks, three days mining, one day transit to port, and three days for unloading. It is therefore anticipated that there will be ~30 mining trips per year, assuming one vessel with a 50,000 t capacity is used, giving 1.5 Mt per annum.

The QP has some concern with regards to the unproven nature of the proposed extraction technique. Trail suction hopper dredging in its proposed form and at these depths is untried, and despite extensive work by Boskalis on detailed aspects of the Project, there are some issues which may require further work. These include movement of the drag-head over the seabed, control on speed of drag-head due to the long tow lines and the accuracy of positioning of the drag-head (which may prove more difficult and less efficient than anticipated by Boskalis). However, the QP is of the opinion that the proposed technique appears to be a viable option to mine the deposit, and that with more research the method can be optimised to successfully mine the phosphorite layer in a feasible manner.

Boskalis has worked with CRP to identify a suitable port where the mining vessel could unload the mined phosphorite, and where the phosphorite could be stored and handled for transfer or export.

The main issues that would affect port selection are:

- distance from mining area;
- access for 11-m-long draft mining vessel and bulk carrier: without dredging;
- method of unloading of the mining vessel: dry (conveyor belt);
- available wharf frontage and storage area: existing, to be modified or to be constructed; and
- environmental criteria (water management) and consenting issues.

There are no other significant infrastructure requirements for the Project.

14.12.4 Markets

CRP's long-term strategic focus is to mine phosphorite from the Chatham Rise in order to supply phosphorite to the fertiliser industry. The phosphorite would be both exported and sold to New Zealand fertiliser manufacturers. CRP commissioned the New Zealand Institute of Economic Research (Schilling, 2013) to conduct an economic assessment as part of the in-progress EIA requirements. While the QP deems this study an important step to assess whether the mineral resource is potentially economically extractable, the study does not meet the definition of a PEA as defined by the *CIM Definition Standards for Mineral Resources and Mineral Reserves* (CIM, 2014).

14.12.4.1 Fertiliser Trials

Several field trials were conducted in the 1960s and 1970s on the applicability of the Chatham Rise phosphorite as a fertiliser (Cullen, 1987). The work is summarised below.

Superphosphate is one of the most widely used fertilisers in the world. It was first developed in the 19th century in England, by mixing sulphuric acid to conventional rock phosphate containing the mineral apatite, a calcium fluoro-phosphate. The resulting water-soluble phosphorus was able to significantly improve yields on a variety of crops. Today in countries like New Zealand it is used extensively for livestock and crop farming.

The agronomic potential of the phosphorite deposits on Chatham Rise was first reported by Norris (1964). However, it was not until 1971 that Buckenham et al. reported the results of a comprehensive series of flotation, calcination, slaking (soil breakdown test), and acid-treatment tests to assess the suitability of Chatham Rise phosphorite for fertiliser production. The phosphorite was found to have a high reactivity, maintained on heating to at least 850°C, which rendered it fit for the manufacture of superphosphate. On the scale of the phosphate reactivity ranges proposed by Hoffman and Breen (1964), the phosphorites from Chatham Rise compared favourably with phosphorites from Nauru, Christmas Island, Florida, and offshore California. In addition, the high availability and short maturing time of both single and triple superphosphates produced from the Chatham Rise nodules was expected to offset, partly at least, the latter's somewhat lower phosphorus content.

One of the primary reasons for the increase in commercial interest in the Chatham Rise deposits in the 1970s and 1980s was the finding that the Chatham Rise phosphorite does not need to be converted to superphosphate as it was an effective fertiliser if just ground, pelletised and applied directly (Falconer, 1989). Pot and field trials have established that, when finely crushed, the phosphorite is suitable for use as a direct-application fertiliser on many New Zealand soil types. It can also still be converted, at increased cost, to superphosphate and triphosphate fertilisers (Cullen, 1987).

Early pot trials by the Fertiliser Manufacturers' Research Association (Roberts & White, 1974), using unprocessed milled Chatham Rise phosphorite, proved encouraging. In the late 1970s, the Soil Science Department of Massey University instituted an investigation of the phosphorite as a direct-application fertiliser, using nodules collected by the New Zealand Oceanographic Institute between 1975 and 1978. Unprocessed, ground and pelletised phosphorite was used in both glasshouse and field trials in which perennial ryegrass (*Lolium perenne*), browntop (*Agrostis tenuis*), and clovers (*Trifolium repens*, *Trifolium subterraneum*), in particular, were grown on a selection of soil types (Mackay et al., 1980; 1984a, b, c). Used as a direct application, the Chatham Rise phosphorite compared very favourably with traditional single superphosphate when tested on acid soils with pH values up to about 5.7. Soils of this type cover a high proportion of hill-country farming areas throughout New Zealand. It was found that, after an initial lag because of the lower solubility of Chatham Rise phosphorite, its herbage yield ranged between 85% and 106% of yield from application of superphosphate (Mackay et al., 1980), and was mainly in the upper half of this range.

14.12.4.2 Phosphate Future Market Expectations

Domestic Market

The use of phosphate-based fertilisers in New Zealand agriculture is extremely widespread. Superphosphate accounts for a third of the fertiliser used in New Zealand by tonnage. In total, phosphate-based fertilisers account for over 40% of the fertiliser used in New Zealand (Schilling, 2013).

Production of superphosphate and other phosphate fertilisers relies largely on imported rock phosphate. Statistics New Zealand's data indicate highly volatile import volumes over the last few years, ranging from 320,000 t in 2009 to 890,000 t in 2010 (Schilling, 2013).

Global Market Supply

The drivers for increased fertiliser demand globally are well known and include:

- world population growth combined with greater affluence, particularly China, which has 19% of the world's population but only 7% of the arable land;
- greater affluence results in a transfer of consumption from vegetable to meat protein, with meat protein requiring 10 times more fertiliser to produce;
- reduced arable land availability due to urban encroachment and the degradation of topsoils by erosion and contamination; and
- an estimated 70% increase in food production required by 2050.

Globally the phosphate industry has been subject to significant changes in recent decades. In the US, Florida's rock phosphate reserves have continued to decline, and in the process pushed North American production down to such an

extent that close to 3.0 Mt of rock now need to be imported into the US annually. Chinese production has continued to grow in recent years, raising the country's share of global production to 40% in 2011. The combination of increasing demand for phosphate-based fertiliser products, and the overall high rock phosphate prices, has also seen mines being commissioned in South America (Peru) and the Middle East (Saudi Arabia). Further expansions have been proposed for Africa, Europe, South America, the Middle East, the FSU, Asia and Oceania over the medium term (2012–2017). Notwithstanding the high overall rock phosphate prices over the last seven years, a recent (since December 2012) downwards adjustment in rock phosphate prices has resulted in the development of many proposed small onshore mines being put on hold.

Existing operations in Morocco have vast resources but the focus is moving to added-value fertiliser products with a USD 15 billion investment in phosphoric acid, and ammonium phosphate manufacturing plants. These expansions require rock phosphate prices to be maintained, particularly as the production costs are also increasing significantly due to various 'social investments' encouraged by recent high profit levels. These include substantially increased salaries and social advantages given to the workers, which are unlikely to be withdrawn. Elsewhere in the Middle East, other rock phosphate competitors such as Syria and Egypt are currently dumping product into the market but face political problems that are likely to have a major impact on their production and export volumes. Algeria has recently commissioned a new phosphoric acid and ammonium phosphate plant and as a result is no longer exporting to the rock phosphate market.

Vietnam, an exporter of low-Cd rock and a direct competitor of CRP, has recently stopped the export of phosphate rock to keep it for domestic phosphoric acid and fertiliser production.

According to commodity market analysts, CRU Group (CRU), the most important issues facing the phosphates industry today are:

- US rock phosphate production has fallen by a quarter since 2007; several factors have contributed to this trend but it can be largely attributed to the decrease in reserves with many of the easy to access, high-grade resources in North America being mined out, resulting in increased production costs; as a consequence, CRU acknowledges ever greater quantities of product will need to be imported from foreign markets;
- increase in rock phosphate production from proposed expansions of Moroccan mining operations; and
- strong domestic demand for rock has seen Chinese rock phosphate production double over the past decade; key challenges for the Chinese are whether this trend can be sustained in an environment of declining run-of-mine grades and increasing production costs.

The monthly price as at March 2026 for the cost per tonne of phosphate in Morocco is around USD 152 per tonne. The average selling price over the last 2 years is around USD 150 per tonne.

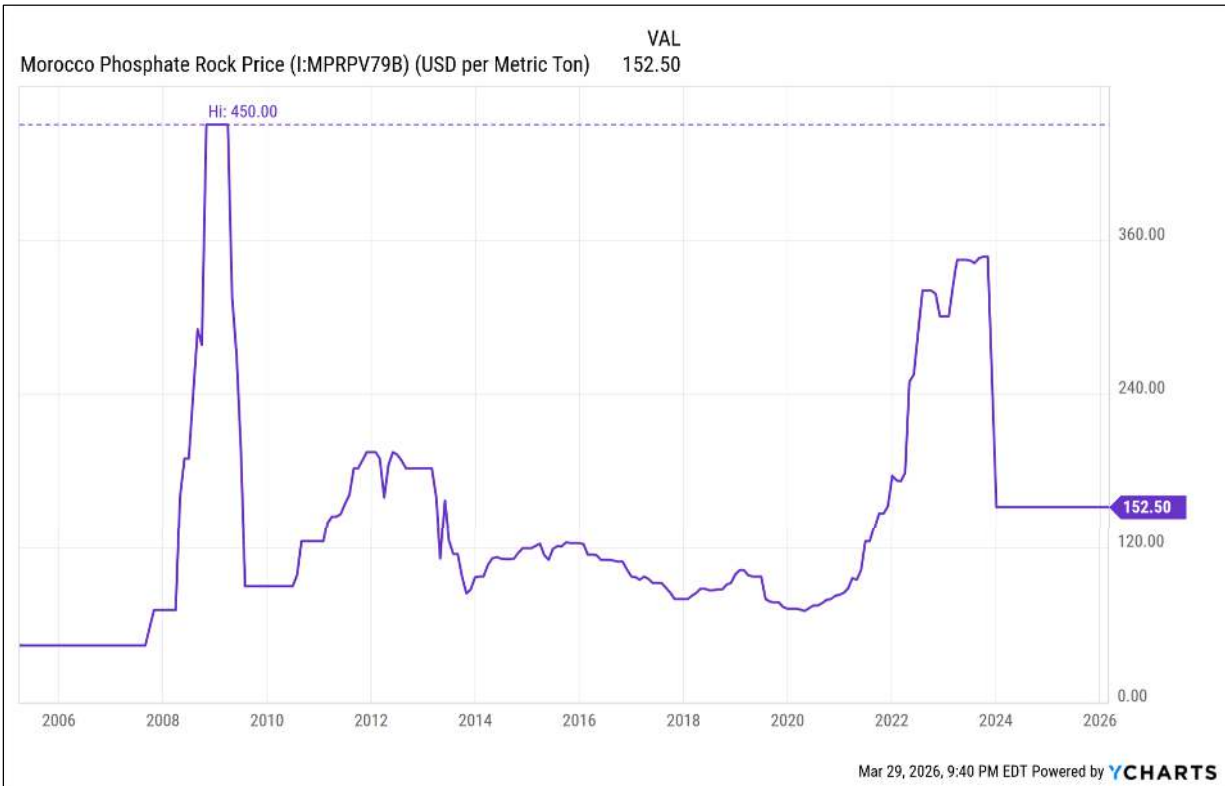


Figure 14-14: Twenty-year price range, USD per tonne of phosphate FOB Morocco (source: https://ycharts.com/indicators/morocco_phosphate_rock_price).

Indicative Pricing of Rock Phosphate

Based on market conditions prevailing in March 2026, the weighted average selling price (WASP), net of freight, for Moroccan phosphate was USD 152 per tonne. This assumed a range of prices that varied by market and the intended use of the product.

Previous extremes of prices, such as those in 2008 and 2023, may not be repeated, but CRP is of the opinion that there is little likelihood of prices collapsing from their current levels. Short-term price variations are not likely to have an impact on the Project as no production is planned for the near future. CRP is confident the predictions of growth in phosphate demand in the next few decades against a background of increasing production costs worldwide, and an unwillingness for the major players in traded rock phosphate to lower prices, will result continued upward pressure on the cost per tonne of phosphate.

To enter the New Zealand market, the Moroccan phosphate product will also be subjected to an additional USD 70 per tonne shipping cost. CRP is confident that due to the Project's proximity to the New Zealand market, any phosphate product to be delivered by CRP to New Zealand is likely to be landed at a discount to the Moroccan product.

14.12.5 Economic Considerations

Following future granting of a Marine Consent, a contract would be entered into with a mining operator (assumed, but not guaranteed, to be Boskalis) to contract-mine and deliver to a New Zealand port 1.5 Mt of dry rock phosphate at an agreed

cost per tonne for a period of at least 15 years. The rock would be stored at a rented portside facility before being either exported (about 75% of production) or shipped to New Zealand customers on an FOB basis.

CRP initially planned key milestones for progress of the Project that would see production start in 2017; however, this timeline relied on environmental approval for the Project being received in 2014. A Marine Consent application submitted by CRP in 2014 was denied.

Mining operations are proposed to be carried out via a contract-mining arrangement, which is expected to be with Boskalis.

CRP has estimated that a dredging contractor will seek to charge a fee in the range of Euros 62–70 (USD 85–97) per landed tonne of phosphorite to cover operating costs, as well as a profit margin. This cost estimate is based on discussions with only one dredge operator and is subject to contractual negotiations that are expected to follow the grant of Marine Consent.

Boskalis and CRP are still investigating options for unloading at various ports and CRP has estimated a further NZD 10.5–14 million (USD 9–12 million) of operational expenditure per annum for onshore operations and corporate costs for the Project from the commencement of production.

As all portside facilities are expected to be leased by CRP, CRP will only need to finance whatever level of stockpile is necessary to ensure customer demands are not affected by interruptions to the mining schedule.

It is assumed that the mining operator would be responsible for almost all capital expenditure in relation to the mining vessel used and would be responsible for providing and managing such vessel. Therefore, the only significant assets that CRP expects to hold are the Mining Permit and the Marine Consent.

Conceptual Sales Forecasts

Conceptual economic studies by CRP assume a long-term phosphorite sale price of USD 125 per tonne for CRP's product mix. These forecasts assume that the product will be sold to a number of identified buyers in eight countries for the following four different uses:

- to make either medium-grade or high-grade superphosphate, direct application, or di-calcic phosphate;
- to blend with other high-grade superphosphates to reduce higher Cd found in other rock phosphate;
- to use as 100% feedstock (without blending) for medium-grade superphosphate; this is a key product for international markets; and
- to use in a direct-application product; New Zealand is a key target market for direct application, which is likely to grow due to its lower environmental impact (low Cd content); this product currently sells at a premium.

Royalties

CRP must pay the higher of:

1. an *ad valorem* royalty of 2% of the net sales revenue of the minerals obtained under the Mining Permit; and
2. an accounting profits royalty of 10% of the accounting profits, or provisional accounting profits, as the case may be, of the minerals obtained under the Mining Permit.

Conceptual mining costs estimated by CRP for landed phosphorite tonnes are lower than the forecast long-term phosphorite price per tonne, indicating a likely profit for the Project. Key risk to the Project is the phosphorite commodity sale price; if this drops by more than 32% from forecast, the Project may become unprofitable.

14.12.6 Environmental Considerations

CRP submitted a Marine Consent application, supported by an EIA, to the EPA on 14 May 2014, followed by an updated EIA on 12 November 2014 to gain consent to begin mining within MP 55549.

On 10 February 2015, a Decision-making Committee (DMC) appointed by the EPA refused CRP's Marine Consent application (EPA, 2015a). At the time of writing of the Report, no appeal against the decision has been lodged with the New Zealand High Court and no new Marine Consent application has been submitted with respect to MP 55549 and the Chatham Rise Project.

The refusal of marine consent was based on the conclusion by the DMC that:

'...mining would cause significant and permanent adverse effects on the existing benthic environment ... [in particular] protected stony corals which are potentially unique to the Chatham Rise.' (EPA, 2015b).

The DMC further stated that:

'Notwithstanding the efforts of CRP to research and substantiate its case, the DMC was left with a lack of certainty about the receiving environment and the adverse effects of the proposal on the environment and existing interests.' (EPA, 2015b).

In a concluding statement preceding the declaration that marine consent had been refused the DMC's summarised its findings:

'The DMC's finding is that the destructive effects of the extractive activity, coupled with the potentially significant impact of the deposition of sediment on the areas adjacent to the mining blocks and on the wider marine environment, could not be mitigated by any set of conditions or adaptive management regime that might reasonably be imposed. The conditions proposed by the applicant, although they went some way towards addressing some of the risks associated with the proposal, did not allay the DMC's basic concern about the adverse effects of the proposal on a distinctive and important marine environment. The various proposals made by the applicant for environmental compensation did not in the DMC's view amount to mitigation.' (EPA, 2015b).

Several issues relating to the DMC's decision and the preceding approval process were highlighted by CRP (2015), politicians (e.g. Smith, 2015) and other groups (e.g. Straterra, 2015) that may have prevented a positive outcome of the application. It has been suggested by observers as well as policy makers that the approval system is not functioning as it is intended. On the other hand, activists and other environmental groups are calling for a moratorium on all seabed mining activities in New Zealand's EEZ.

While it is unclear how this situation will develop in the future, the QP's opinion is that:

- the quality and amount of the data that CRP has presented to the EPA is significant; collection of additional data, or more modelling of key environmental factors (e.g. sediment plumes) will positively contribute to any future decisions;
- CRP now has a list of specific issues that it knows are key issues that require further work; and
- resubmitting the application will be under a new DMC (i.e. it will be unbiased), and possibly under the Fast-Track Approvals process.

CRP intends to continue to work with the EPA to seek further clarity on the interpretation of the EEZ legislation and the EPA's policies and procedures for managing the consent process. CRP would incorporate any changes into its plans for resubmission of a Marine Consent application. Importantly, in light of the above points, when assessing the potential for eventual economic extraction, in the opinion of the QP, any new application by CRP will stand a more than equal chance of being approved.



23. Adjacent Properties

There are no properties adjacent to the Chatham Rise Project.



24. Other Relevant Data & Information

There is no additional information or explanation necessary to make the Report understandable and not misleading.



25. Interpretation and Conclusions

A variety of sampling techniques and measuring techniques have been used during exploration of the Chatham Rise, with varying degrees of success. With respect to mineral resource estimation, several issues affect the historical and modern sampling undertaken; these include large sample location errors, variable sample sizes, lack of documentation of sampling procedures, limited quality control, invalid calculation assumptions, and visual estimations of phosphorite contents. All of these add errors to the grade estimation process. Most of the work carried out by the QP has focussed on a thorough review of all available data to understand the implication of each of the various errors and assumptions on the quality of the data, and to identify data that are suitable for the classification of an Inferred Mineral Resource. On a small scale, the deposit is also complicated by high local variability caused by the coarse-grained nature of nodules and post-depositional modifications from icebergs.

After reviewing the sample data and procedures, the QP considers the data collected during the *RV Sonne* cruise to represent the best-quality data collected for the purpose of mineral resource estimation. The locations of *RV Sonne* data points were determined using underwater transponders to reduce relative position error, and the *RV Sonne* used a large pneumatic grab sampler that allowed adequate penetration of the sand horizon and was capable of recovering large samples (0.8 m³). The *RV Sonne* sampling process was also very well documented and extensively reported in post-cruise research studies. The QP has recalculated grade data from the raw datasheets and removed samples that were compromised (e.g. by sample washing, etc.).

The QP reviewed the *RV Valdivia* data, which were collected using a much smaller Van Veen grab sampler. The grab sampler was capable of recovering a 0.12 m³ sample and had some difficulty penetrating the nodule-rich sand consistently. The QP reviewed the *RV Valdivia* dataset for bias, and a large number of samples were classified with a low ranking and removed from the MRE.

The *RV Sonne* and *RV Valdivia* datasets are the most important for quantifying grade and volume estimation of the Chatham Rise phosphorite deposit, with other earlier datasets being too widely spaced and later datasets being in small numbers, closer spaced but collected in isolated groups.

The QP's analysis to date indicates that a potentially economically extractable phosphorite mineral resource exists in the Project area. Several high-profile sampling cruises, mostly independent from each other, have all identified grades of economic interest within the same area. These cruises have been well documented and specific knowledge on sampling systems has been retained and included in the Report, with contributions from Dr Robin Falconer and Dr Hermann Kudrass, who were part of the earlier sampling cruises on which most of this MRE is based. Furthermore, CRP has carried out extensive work (conceptual mining studies, market analysis, recovery studies and environmental studies) to further support that the mineral resource is potentially economically extractable.

The overall amount of sampling within the mineral resource area is abundant, and, within each cruise domain, there are data points for other cruises that, to various degrees of acceptance, confirm the tenor of mineralisation. There may well be comments to add to the quality of some of the sampling, but the sampling coverage warrants a classification of at least part

of the deposit in the Inferred category in accordance with NI 43-101 and the CIM as the CIM Definition Standards on Mineral Resources and Mineral Reserves (May 2014).

Uncertainties and risks related to economic and environmental considerations and resource estimations are discussed in Section 14. The QP notes that the key risk to the Project is the phosphorite commodity sale price, as if this drops by more than 32% from forecast, the Project may become unprofitable.

Mining in New Zealand is a sensitive subject, and the QP notes CRP must effectively monitor and address any issues that may impact the granting of any future environmental consent applications.



26. Recommendations

26.1 Work Programme

The QP suggests a two-staged work programme.

A first stage (Phase 1) would focus on further integrating all existing geological and environmental data to increase the confidence in both the mineral resource estimate and environmental models.

The current MRE is based on historical data and classified as an Inferred Mineral Resource because of its relatively low confidence. Contingent on the results of Phase 1, the QP recommends that for the second stage in the work programme (Phase 2), further seafloor sampling be undertaken to both increase the confidence in the established MRE and to extend the boundaries of the resource, predominantly towards the west where currently low-quality *RV Valdivia* data indicate an exploration target of 3 to 4 Mt phosphorite at potential grades of 200 to 300 Ph kg/m³. Increasing the confidence in the current MRE by additional properly located and documented sampling will give CRP and Boskalis the grade and geological confidence in the phosphorite deposit to allow them to further develop mining plans and economic studies.

The QP recommends that further exploration includes, but is not limited to:

- 400 × 400 m seafloor sampling using a large-sized pneumatic grab sampler;
- a thorough QA/QC programme for future sampling campaigns;
- logging of data indicating depth of mineralised sand layer;
- ROV transects of sample sites to confirm sample quality and depth of sample; and
- detailed bathymetric survey of mining blocks to delineate barren zones from outcrop, icebergs furrows and pits.

Based on previous work programmes, up to 30 samples can be collected each day. More samples can be collected if work can continue through the night. On the 400 × 400 m grid there will be about 9 samples for every 1 km² of seafloor. The next phase of sampling required to increase the resource to Indicated classification can be staged to reduce exploration expenditure, but will need to deliver enough resource volumes that feasibility studies can use and that indicate an economic mine life over a sustainable period. This may require delineating resources over 150 km² of seafloor to allow for approximately five years of mining based on current mining concepts. Approximate costs of this programme are illustrated in Table 26-1.

Table 26-1: Proposed work programme and cost.

Phase	Description	Cost (USD)
Phase 1: Data modelling	Further data integration and modelling	0.3M
Phase 2: Seafloor sampling	Sampling and resource update	4.7M

26.2 Seafloor Sampling

Ideally, grab sampling should be conducted on a 400 × 400 m grid in zones identified as having high economic potential as mining operations. This distance is regarded as adequate for delineating short-range variability (<1,000 m) in the phosphorite deposit illustrated in Figure 14-2. The grid dimension may need to be further adjusted depending on local geological conditions and results. Using a grid-based sampling design will reduce the issue of clustered data and cover a large area efficiently.

The QP recommends undertaking the sampling using a grab sampler of similar capabilities to the *RV Sonne* grab sampler. A minimum of 0.8 m³ will reduce the effect of the nuggety nature of the phosphorite, allow meaningful duplicates to be taken, both of the field sample and for subsampling, and allow less-disturbed samples of the full sand depth to be collected. The jaws need to be hydraulically controlled, preferably from the deck and triggered as the grab sampler hits the seafloor. The grab sample must be fully sealed to protect it from washing.

Sample processing can be completed either at sea or on land. However, the whole sample needs to be processed for separation.

Data collection prior to processing needs to include:

- accurate measurement of the sample volume of the whole grab sample;
- accurate measurement of the sand volume/thickness;
- detailed descriptive logs of profile and visual estimation of phosphorite content;
- graphic profile of the grab sample with depths of phosphorite occurrences; and
- collection of photographic record of sample profile.

Sample processing and analysis requires reducing the sample down to one or more fractions over 2 mm. The system needs to use a standardised sieve which can handle the size of sample without overflowing or becoming blocked, and can be cleaned between separation runs.

Data requirements are:

- accurate measurement of the weight or volumes of sieved fraction(s); and
- estimation of phosphorite content using a standardised abundance reference.

The results will allow accurate calculation of phosphorite content of the sand layer (kg/m³). The grab sample volume would need to be estimated based on the known grab sampler dimensions and height of the collected sample in the grab sampler.

26.3 Data Quality

As part of the resource reporting requirements, the sampling programme requires a suitable data quality programme to ensure the sample collection is undertaken according to best practice and controlled.

The QP proposes using the following practices to meet the appropriate data quality requirements:

- clear documentation of sampling and other procedures;

- collection of duplicate grab samples from the seafloor (<10 m separation), 5% of the samples;
- photograph of the sample site after collection (ROV or similar, or a video camera mounted on the grab sampler) with scale to determine sample depth, and void shape of the sample on seafloor; and
- full phosphorite separation conducted on 3% of the samples, where the phosphorite material is separated from the non-phosphorite material in the sieved fractions.

Any further subsampling or reduction of sample size for further analyses needs to be conducted under controlled conditions using proper splitters capable of handling large nodules and sample sizes of several hundred kilograms. Sub-samples will be required for additional geochemical analyses and density testing.

The QP recommends routine laboratory analysis on all samples with phosphorite for P_2O_5 . The quality of these analyses should be controlled with standards and blanks.

The QP also recommends analyses of the levels of deleterious elements such as As, Cd and U.



27. Certificate of Qualified Person: <<Name of Author>>

I, **René Sterk**, MSc FAusIMM CP(Geo) MAIG (RPGeo) MSEG MInstD of 349 Coast Road, Dunedin 9471, New Zealand, do hereby certify that:

- I am Managing Director and a Principal Consultant at RSC Consulting Ltd, located at 245 Stuart Street, Dunedin 9016, New Zealand.
- The Technical Report to which this certificate applies is titled '*NI 43-101 Technical Report on the Chatham Rise Phosphorite Project, New Zealand*', with an effective date of 29 April 2026.
- I was awarded an MSc degree in Structural Geology and Tectonics from the Vrije Universiteit Amsterdam in 2002.
- I am a Fellow, registered with the AusIMM (FAusIMM) in Australia (recognised overseas professional organisation) as member 303499, in good standing.
- Throughout my career, I have practiced continuously as a mining geologist, exploration geologist, manager and consultant for mining and exploration firms in a range of commodities, including polymetallic nodules. I have undergone continual professional development with recognized courses and training seminars.
- I have read the definition of 'Qualified Person' set out in NI 43-101 and certify that by reason of my education, affiliation with professional associations (as defined in NI 43-101), and past relevant work experience, I fulfil the requirements to be a 'Qualified Person' for the purposes of NI 43-101.
- I completed a site visit (personal inspection) of the Project's subsampling site on 16 January 2014.
- I am responsible for all sections of this Technical Report.
- I am independent of the issuer, Chatham Rock Phosphate Ltd, applying all of the tests in Section 1.5 of National Instrument 43-101.
- I have previously provided exploration advice regarding the Property that is the subject of this Technical Report. I was the Qualified Person for a Mineral Resource estimation that was reported in accordance with the in accordance with NI 43-101 and the CIM Definition Standards on Mineral Resources and Mineral Reserves with an effective date of 6 July 2015.
- I have read NI 43-101 and Form 43-101F1, and this Technical Report has been prepared in compliance with that Instrument and Form.
- At the effective date of this Technical Report, to the best of my knowledge, information and belief, this Technical Report contains all scientific and technical information that is required to be disclosed to make this Technical Report not misleading.

Signed this Dunedin, New Zealand.

(Original signed and sealed)

René Sterk, FAusIMM CP(Geo) MAIG (RPGeo) MSEG MInstD

Managing Director and Principal Consultant, RSC Mining & Mineral Exploration

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