

From exploration to extraction: The consequences of resource morphology for mining operation on the Chatham Rise

Campbell McKenzie¹, Ray Wood², Robin Falconer³

¹Chief Operating Officer, Kenex Limited, 16 Oroua Street

Abstract

Substantial consideration has been given to the implications that the morphology of the Chatham Rise deposit will have on mining operations. The glacio-tectonic processes involved in the distribution of nodules on the rise have in several areas been quite significant. The recent cruises by Chatham Rock Phosphate Limited (CRPL) have collected data which has affirmed the assumptions previously made and catered for in historic resource estimations.

The deformation and displacement of the phosphorite during glacial periods and the redistribution of the mobile sand during interglacial periods is interpreted to have produced a highly variable pattern of phosphorite concentration (kg phosphorite/m²) and coverage (% phosphorite/sample weight). The phosphorite resource probably has a significant spatial variability at a scale of tens of metres. Results of recent surveys show phosphorite-rich patches alternating with phosphorite-poor areas at distances of less than 20 m.

The high spatial variability of the deposit has had a bearing on how historical information for the project has been regarded and integrated with the recent exploration approach and data collection process. This coupled with the proposed extraction tool has influenced the size, nature, extent and siting of the proposed mining blocks.

Keywords: Chatham Rise, phosphate, marine mining.

Introduction

Phosphate nodules were discovered on the Chatham Rise in 1950 by the New Zealand Geological Survey. (Reed and Hornibrook, 1952). Government and commercial exploration of the nodules took place over the ensuing decades through into the early 1980's (e.g. Global Marine 1968; Earth Scientists Pty Ltd 1973; Pasho 1976; Cullen 1980). The most significant period of activity occurred with the collaborative efforts of the New Zealand and German governments in 1978 and 1980 where scientists collected bottom samples using a seafloor grab (1000+ samples) and 2600km of deep towed seismic data (Von Rad 1984).

This exploration identified a 25Mt resource of phosphate in a relatively thin sand/silt layer (Kudrass, 1984). Occurring as sand and nodules, the phosphate most commonly falls in the 1-150mm size range lying on and within the seafloor layer (Figure 1). Average P₂O₅ content is 22% and resource concentration averages 66kg/m² in the prospective areas (Wood; 2012).

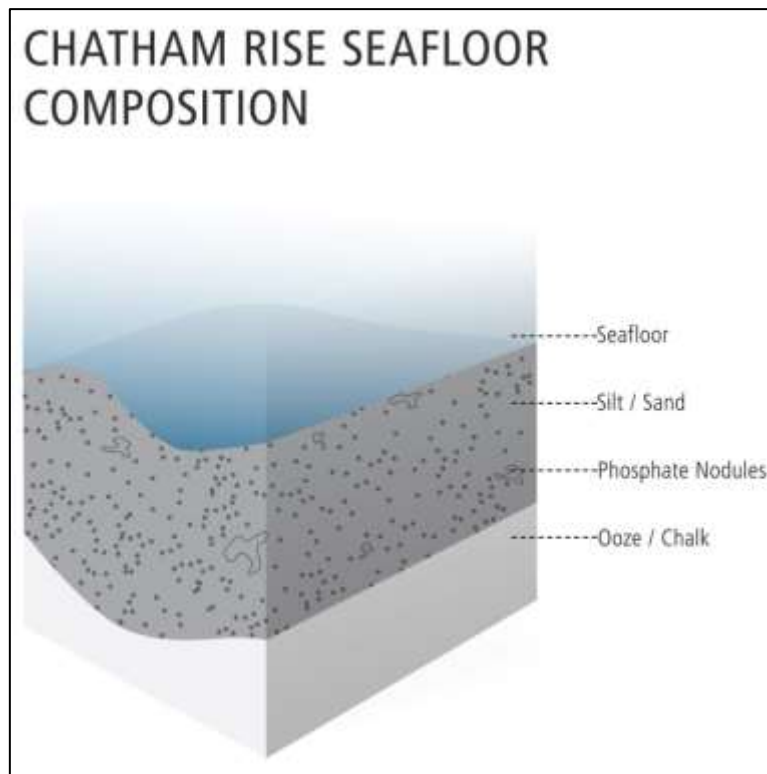


Figure 1: Schematic cross section of Chatham Rise seafloor composition.

The phosphorites were formed by the phosphatisation of a burrowed and bored Miocene chalk. The phosphate was concentrated by dissolution, burrowing and winnowing of the non-phosphatised material. The deposit was subsequently modified by icebergs in the Pleistocene (Kudrass and Von Rad, 1984). The level of disturbance by the icebergs was not apparent until the collection of new exploration data – multibeam bathymetry- in 2011 and 2012.

The implications of this deposit morphology, particularly the spatial variability, has influenced the collection of additional data and planning of mining blocks within the applied for mining permit area.

Local Geology and Morphology

Glacio-tectonic processes have had a significant influence on the morphology of the phosphate resource and Rise in general. The seafloor of the central saddle of the Chatham Rise is intensively shaped by the impact of icebergs. Furrows caused by movement of grounded icebergs and pits probably produced by rotating icebergs are the most important elements, ranging in scale from a few meters to hundreds of meters. This impact shaped the morphology by excavating the chalk up to a depth of 15 m along furrows and in the pits. The excavated chalk together with the top layer of phosphoritic sand is spread along the rims of the furrows and pits. This process produced the high variation of the phosphorite with respect to thickness and coverage.

This massive impact was probably repeated during each of the five main Pleistocene glacial periods. In the long interglacial periods the sea floor was smoothed by winnowing of the silt and sand, filling of the depressions, and burrowing and dissolution of the exposed chalk.

Some previously buried phosphorite nodules were thus available for further phosphate enrichment at the surface.

The distribution of the phosphorite is shaped by these glacial and interglacial processes and consequently has a high lateral variability (on a scale of less than 20 m) (Kudrass and Von Rad 1984; Kudrass. Pers. comm.)

Morphology of Furrows

Furrows are the most prominent sea floor features seen on the multibeam swath bathymetry data in the CRPL licence area (Figure 2). They appear at all scales of observation. Their widths range from a metre to 240 m. Along longer furrows the widths of the cross sections can vary by a factor of two. The largest furrow has excavated 30 metres of chalk. Most of the larger furrows can be traced a few kilometres. The longest furrow is more than 25 km long. Large furrows are predominantly oriented northwest-southeast to northeast-southwest. Smaller furrows are much more variable in their directions. The larger furrows often have elevated rims of a few meters, where chalk is frequently exposed or is covered by a thin layer of glauconitic-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.

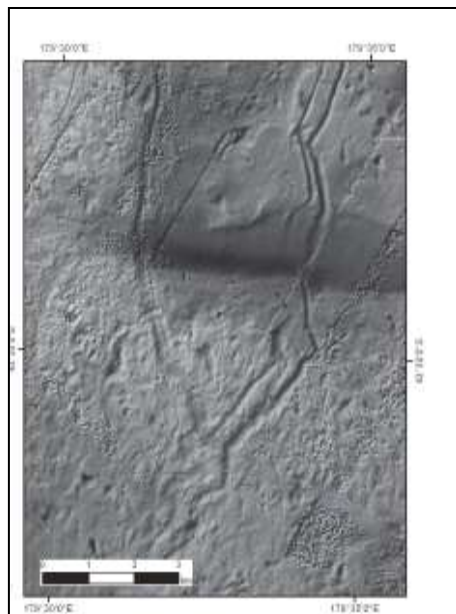


Figure 2: Linear ice berg furrows on the Chatham Rise shown in multibeam swath bathymetry data.

Morphology of pit marks

Pit marks with a diameter of a few metres are visible on the ROV multibeam data; the larger ones visible on the regional bathymetric maps have a diameter of up to 700 m. The smaller pits are frequently round (up to diameter 50 m), the larger pits (up to a diameter of 300 m) have two different shapes: a triangular and lenticular shape with smooth well defined rims or a subrounded shape with highly irregular rims. The depth of the medium-sized pits is about 10m. Pits occur in almost all water depths of the investigated area. They may be made by grounded icebergs.

Understanding of the resource

The deformation and displacement of the phosphorite during glacial periods and the redistribution of the mobile sand during interglacial periods is interpreted to have produced a highly variable pattern of phosphorite concentration (kg phosphorite/m²) and coverage (% phosphorite/sample weight). The phosphorite resource probably has a significant spatial variability at a scale of tens of metres. Results of recent surveys show phosphorite-rich patches alternating with phosphorite-poor areas at distances of less than 20 m.

The high spatial variability of the phosphate resource can probably only be accurately mapped with closely spaced cores (which is cost prohibitive) or possibly with a dense grid of high-resolution seismic reflection data – which the outcomes would be uncertain given the thin sand layer (typically less than 0.70m). The mining device is therefore being developed to cope with these rapid changes. The phosphorite may be concentrated near the surface (possibly most commonly on elevations) or may be primarily buried below the surface (possibly most commonly in depressions).

There is little evidence of steep slopes in the bathymetry data. Modification of sea floor features by burrowing; dissolution, winnowing, and transport of the silt and sand have smoothed the surface (Kudrass and Von Rad 1984).

Estimates of mineral resource

Resource estimates for the deposit have been based on analysis of grab samples obtained from the 1978 RV Valdivia cruise (Kudrass and Cullen 1982) and on analysis of grab samples from the 1981 RV Sonne cruise (Kudrass 1984). CRP has re-evaluated this data and considers that that the historical estimates and moved ahead with additional project investment on this basis.

Estimated abundances of phosphorite nodules from the grab samples (expressed as percent per square metre of sea floor) were converted to volumes by multiplying the percent abundances by the thickness of sand at each grab sample site to calculate cubic metres of phosphorite nodules. The 1978 RV Valdivia data were obtained from 689 samples. Nodules were either weighed (or their weight extrapolated) from volumes on the basis of weight-volume curves. An assumed density of 2.65 kg/m³ was used to obtain mass from volume. Nodule abundance was estimated using two approaches. The first approach used a simple calculation based on the abundance of nodules at each sample site, the thickness of nodule-bearing sand at each site, and an average area of influence for each sample. The area of influence was 0.33 km² in the eastern part of the survey area and 0.77 km² in the western part (Figure 3, Va-E and Va-W below). A total area of 227 km² was estimated to contain 14 Mt of nodules with an average abundance of 61 kg/m².

A second geostatistical approach was also applied to the 1978 data. Variographic analysis and two-dimensional kriging of nodule abundance and distribution were carried out over 382 one-kilometre square blocks. Estimated abundances ranged from 2,000 to 44,000m³ of nodules per square kilometre. At a lower cutoff of 20,000m³/km², this approach also produced an estimate of 14Mt with an average abundance of 69kg/m². At a lower cutoff of 15,000 m³/km², the area was estimated to contain 18Mt of nodules. Phosphate analyses of 63 bulk samples of nodules from the 1978 sampling program gave P₂O₅ grades ranging from 20.1% to 23.7% with most in the range of 21.0% to 22.5%.

The 1981 RV Sonne cruise sampled, in relative detail, four areas with an aggregate area of 170 km². Kudrass (1984) noted that the variography of nodule abundance had a high nugget value, indicating high local variability in nodule abundance at ranges as small as 100m. The quantity of nodules was estimated by two-dimensional kriging and by estimation of mean abundance from cumulative frequency curves. Kriging gave an estimate of 9.5Mt with an average abundance of 57 kg/m² for an area of 167 km² (Figure 8.1). The cumulative frequency approach gave an estimate of 7.5 Mt with an average abundance of 54 kg/m² for an aggregate area of 140 km².

A portion of the 1978 RV Valdivia area of investigation overlaps the sample area of the 1981 RV Sonne cruise (Figure 3). When the overlap area is removed, the RV Valdivia and RV Sonne survey areas together were estimated to contain 25 Mt of nodules in 378km² with an overall abundance of 66 kg/km² (Kudrass, 1984).

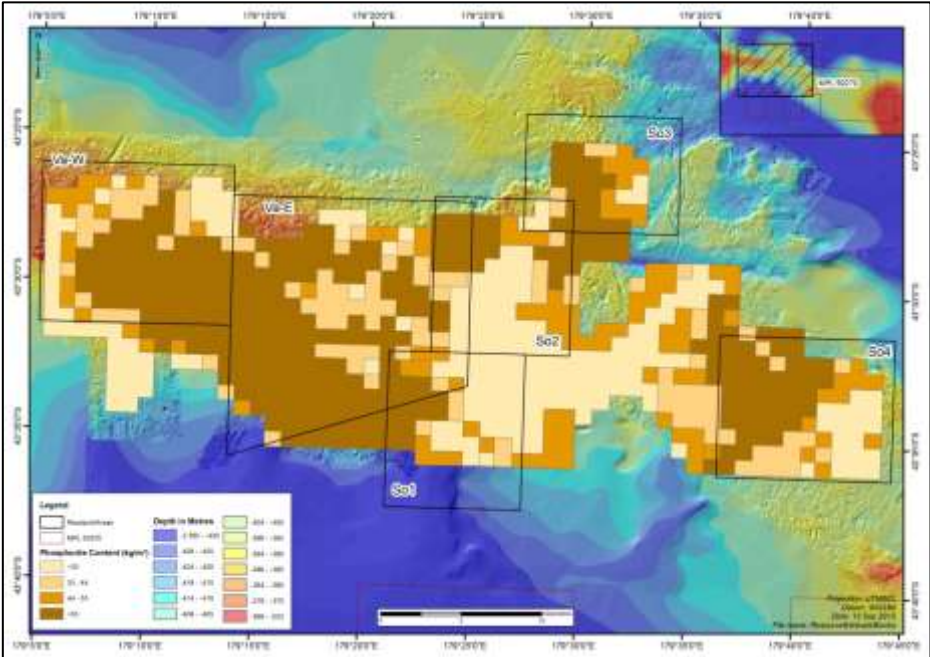


Figure 3: Resource Estimate blocks for Valdivia and Sonne data from Kudrass 1984

The influence of resource morphology on planned mining operations.

The CRPL team which includes dredging partner Royal Boskalis Westminster NV, has given substantial consideration as to the implications of the Chatham Rise deposit morphology on mining operations. The exploration cruises undertaken by CRPL in (2011-12) have collected data which has affirmed the assumptions previously made and catered for in the resource estimations.

Detailed bathymetric data has enabled the greater certainty on the topography of the seafloor surface. CPT information and analysis of recently collected bulk samples has allowed geotechnical engineering design to be conducted with new data. This data combined with the analysis of the historical sample data has enabled zones for mining to be planned.

Selection of the initial zones of mining is based on all data available, with the Sonne and Valdivia data being the main data source.

The primary factors influencing the choice of the initial mining areas are the bathymetry (surface morphology), average sediment thickness, average phosphate coverage (kg/m^2) and the amount and type of other geotechnical and geological information available for interpretation. Mining areas are chosen to include a range of seafloor morphologies, phosphate coverage and sediment thickness.

Statistics for each proposed mining block area were derived from the data. Statistics for the bathymetry are derived from the regional multibeam swath bathymetry data collected by the 2011 and 2012 surveys. Statistics for the estimated resource include the average phosphate coverage (kg/m^2), average sand thickness (cm), estimated total resource (T), and estimated mine resource (T).

The average phosphate coverage values (kg/m^2) are derived from the Sonne and Valdivia sample analyses values. The measured phosphate coverage values were gridded at 100 m cell size using inverse distance weighted interpolation in Arc Map GIS. The interpolated result was clipped to the mine block areas. The mean phosphate coverage value for each mining area was determined from the interpolated grid.

The average sand thickness values (cm) are derived from the Sonne and Valdivia cruise grab sand penetration values. The measured values were gridded at 100 m cell size using inverse distance weighted interpolation in Arc Map GIS. The interpolated result was clipped to the mine block areas. The mean sand thickness value for each mining area was determined from the interpolated grid.

The estimated total phosphate resource (T) was estimated from the interpolated phosphate coverage values derived from the Sonne and Valdivia sample analyses. The estimated total resource was calculated by multiplying the average phosphate coverage value by the area of the mining area (10 km^2).

Conclusions

The Chatham Rise Phosphate deposit is unique and presents a number of interesting challenges from the perspectives of exploration, engineering, environmental management and extraction. However, CRPL has established a framework to use the historical and recent data in a manner that has given further confidence to invest further in the project.

References

- Cullen, D.J. 1980. Distribution, composition and age of submarine phosphorites on Chatham Rise, east of New Zealand. Special publication / Society of Economic Paleontologists and Mineralogists, 29: 139-148.
- Earth Scientists Pty Ltd 1973. A report on the economic potential of the Chatham Rise phosphorite. NZ Petroleum and Minerals MR 2733. 86 pp.
- Global Marine Inc. 1968. Compendium of the geology and phosphorite deposits of Chatham Rise, east of New Zealand. NZ Petroleum and Minerals MR 2729. 40 pp.
- Kudrass, H. 1984. The distribution and reserves of phosphorite on the central Chatham Rise (Sonne-17 cruise 1981). Geologisches Jahrbuch. Reihe D: Mineralogie, Petrographie, Geochemie, Lagerstaettenkunde 65: 179-194.

- Kudrass, H. and von Rad, U. 1984. Geology and some mining aspects of the Chatham Rise phosphorite deposits; a synthesis of Sonne-17 results. *Geologisches Jahrbuch. Reihe D: Mineralogie, Petrographie, Geochemie, Lagerstaettenkunde* 65: 233-252.
- Pasho, D.W. 1976 Distribution and morphology of Chatham Rise phosphorites. Wellington: DSIR, NZ Oceanographic Institute. *New Zealand Oceanographic Institute memoir* 77. 27 p.
- Reed, J.J. and de B Hornibrook, N. 1952. Sediments from the Chatham Rise. *New Zealand Journal of Science and Technology, Section B: General Section* 34. 3: 173-188.
- Von Rad, U. 1984. Outline of Sonne cruise SO-17 on the Chatham Rise phosphorite deposits east of New Zealand. *Geologisches Jahrbuch. Reihe D: Mineralogie, Petrographie, Geochemie, Lagerstaettenkunde* 65: 5-23.
- Wood, R; van Ralte, G. and Castle, C. 2012. Marine Phosphate on the Chatham Rise, New Zealand: geology, ecology and a mining plan. 2012 AusIMM New Zealand Branch Conference proceedings: 483-490