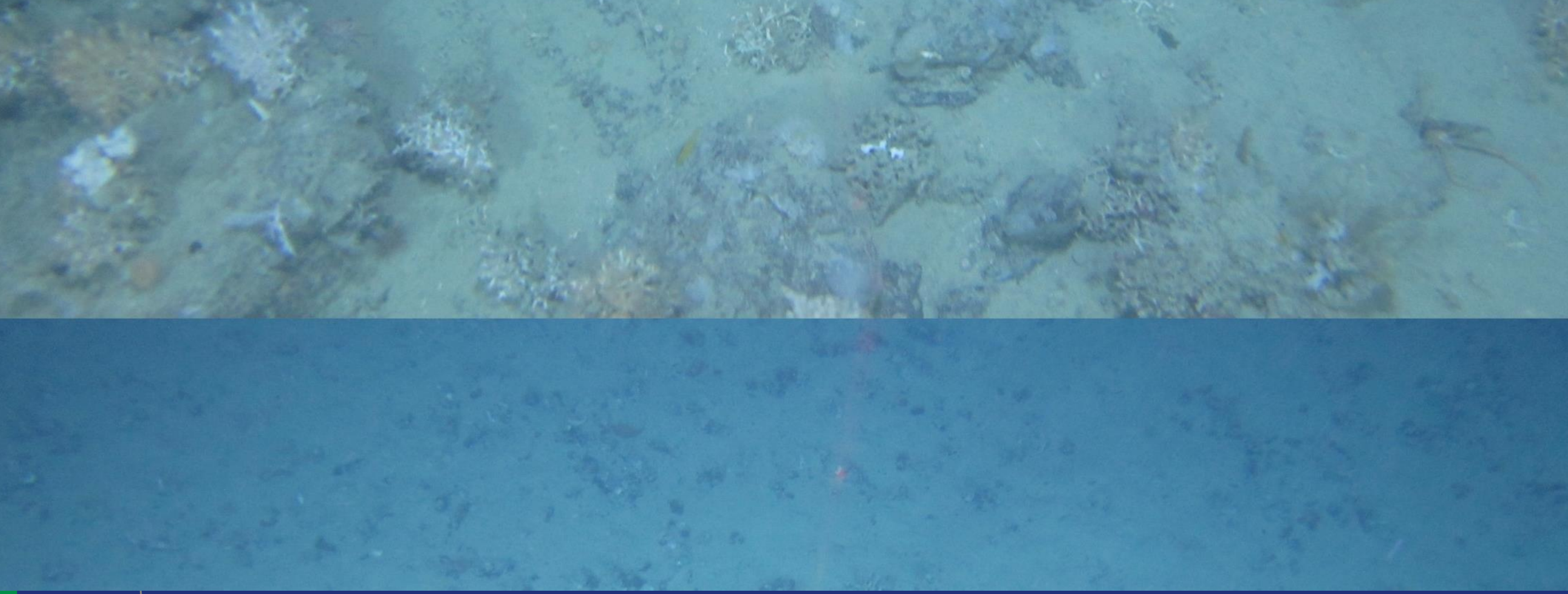


Mineral Prospectivity Modelling as a tool for resource and mine development

Simon HH Nielsen[1], Ray Wood[2]

[1]Kenex
[2]CRP

Background

- Chatham Rise phosphate deposit, sought to be mined by Chatham Rock Phosphate (CRP)

- Mining License granted, Marine Consent Application refused by EPA

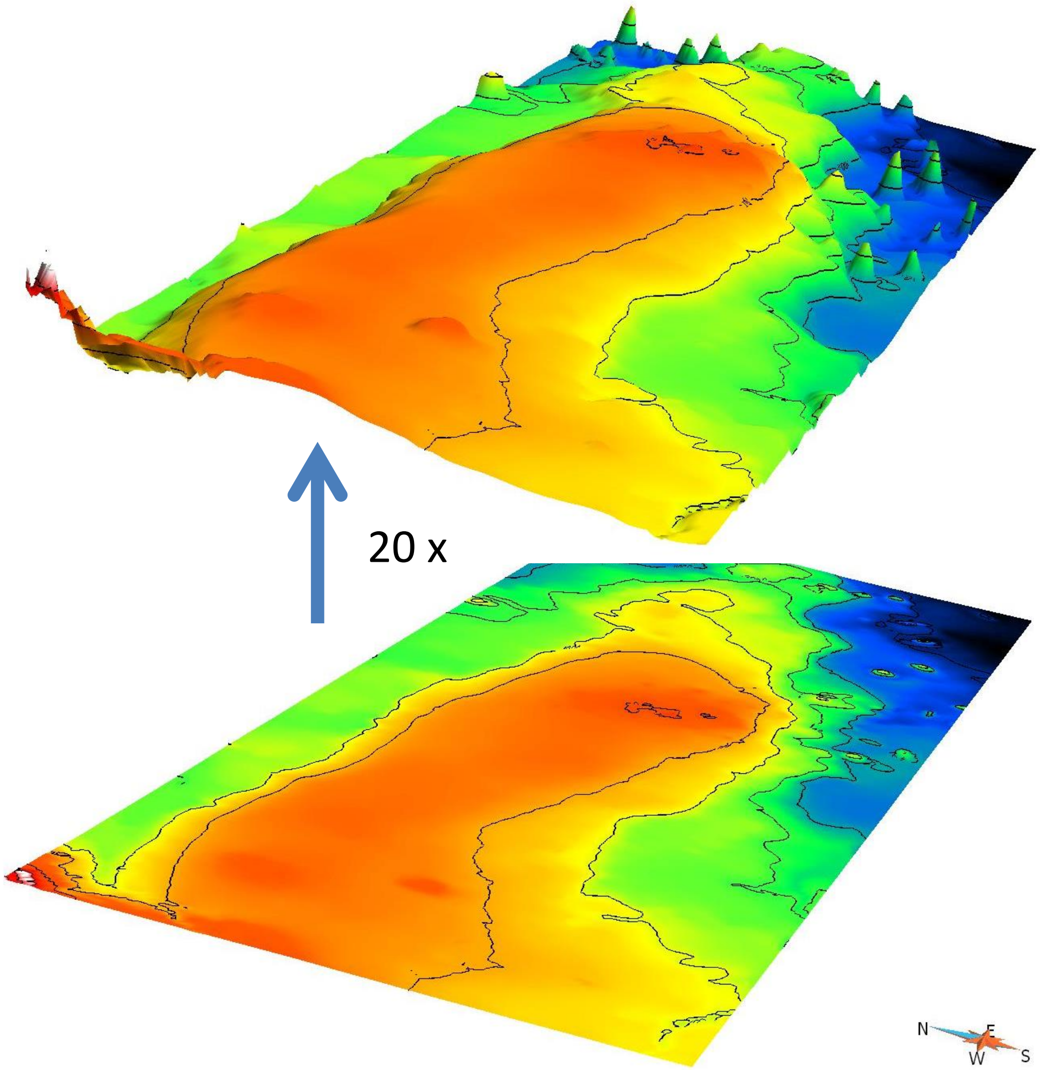
- Reason: Lack of certainty of effect on receiving environment, including protected stony corals

Kenex involvement

- Fieldwork planning and participation
- Prospectivity and resource modelling
- Permit management

Chatham Rise

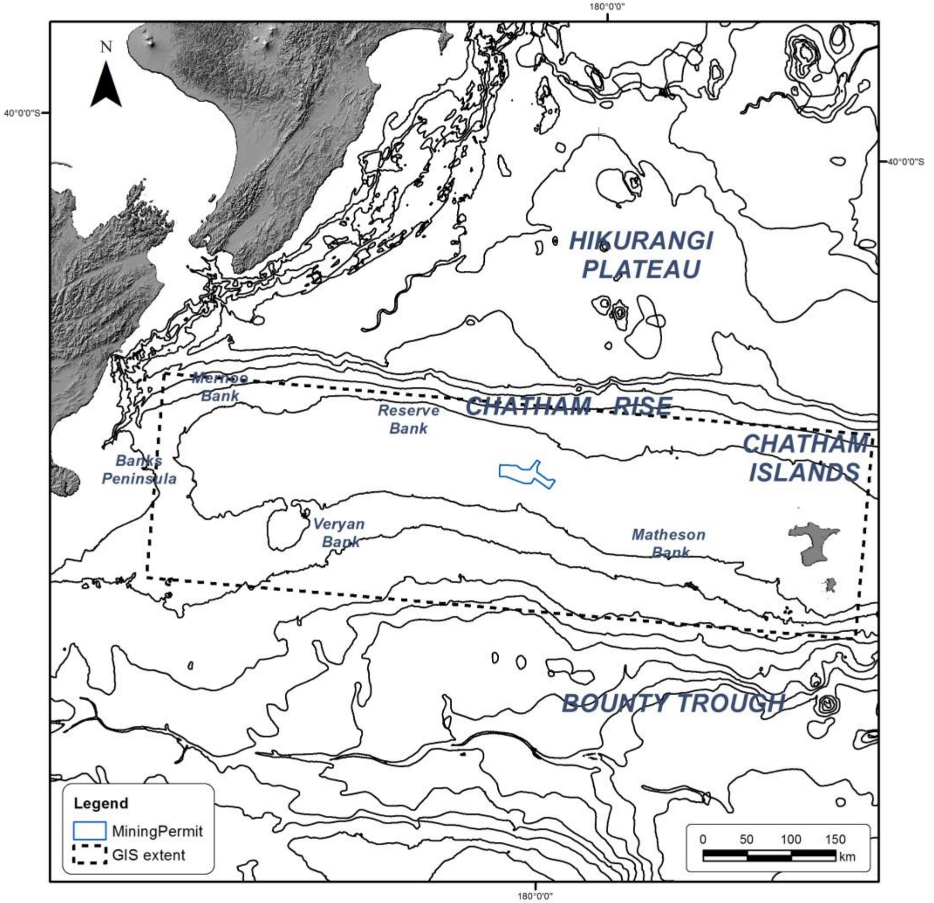
- 1000 km long structural high
- 125 – 200 km wide
- 400 m water depth at crest
- 4 km depth in Bounty Trough
- 2.5 km at Hikurangi Plateau



Chatham Rise - Data

CRP Mining Permit – 820 km^2

450 km from mainland New Zealand

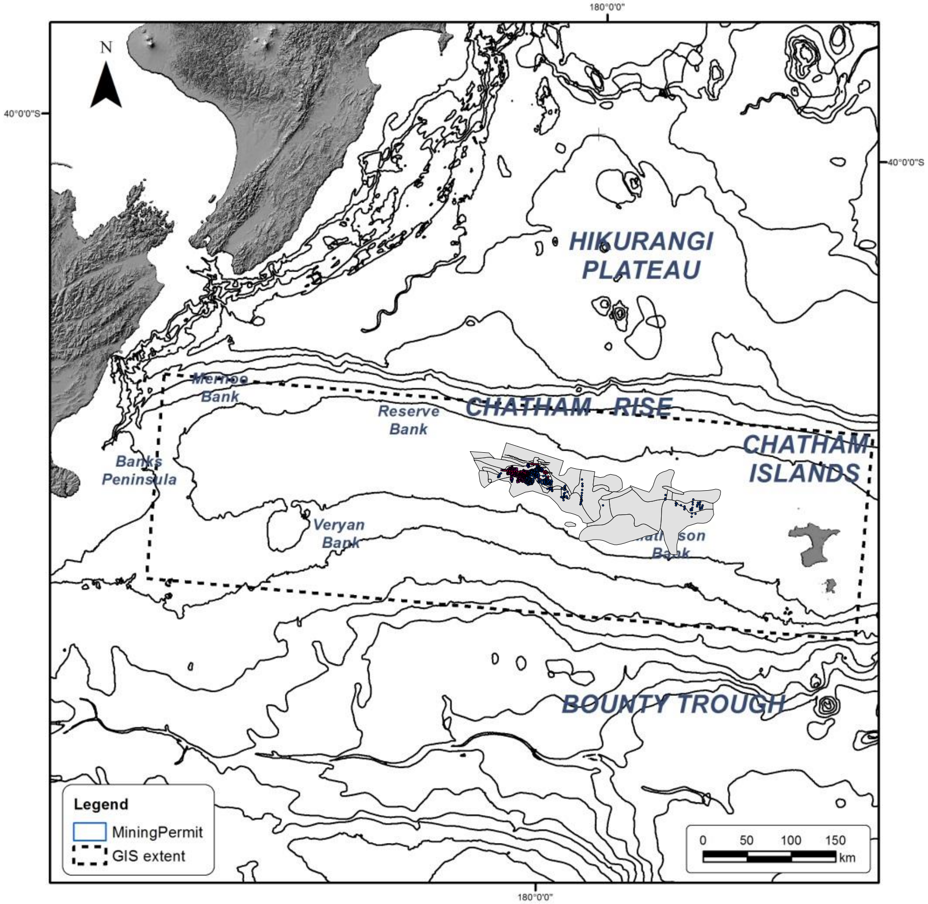


Chatham Rise - Data

Seismic Survey
Data collected by *Sonne* in 1981, base for facies model.

Grab samples
Data collected by *Valdivia i*n 1978, *Sonne* in 1984, and *Dorado Discovery* 2012

Bathymetry
Multibeam bathymetry collected by *Dorado Discovery* in 2011-2012

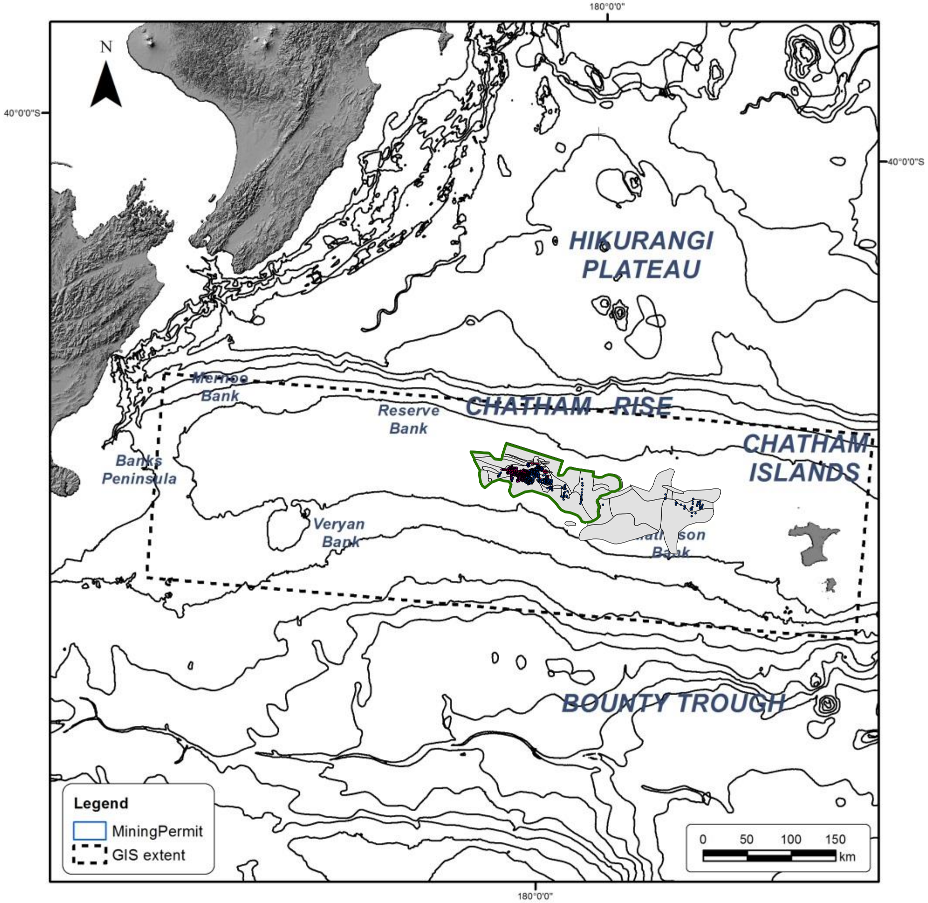


Chatham Rise – Model 1

Weights of Evidence

Data-driven model in best studied area

- Quantifiable, based on spatial statistics
- Can handle “no data” areas
- Output includes standard deviation and confidence maps



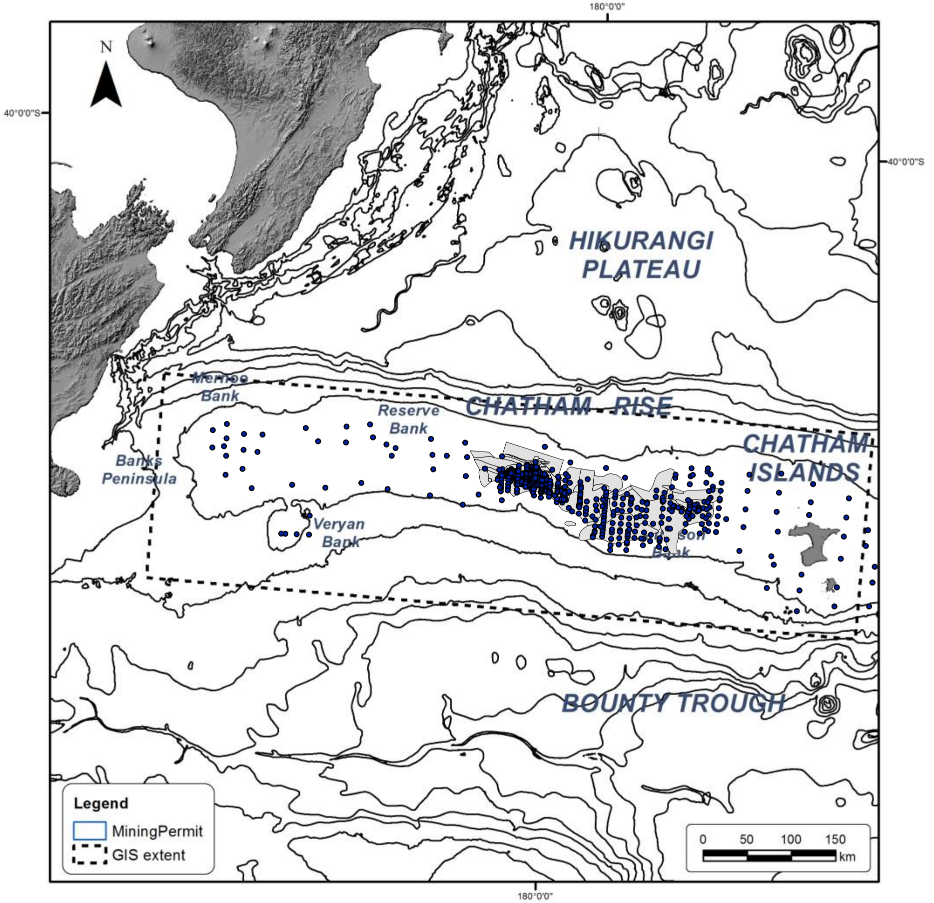
Model area: 6540 km^2

Chatham Rise – Regional Data

Regional dredge sampling
Global Marine in the 1960s

Regional seismic survey
Compiled by NZGS in 1989

Regional bathymetry
Compiled by NIWA

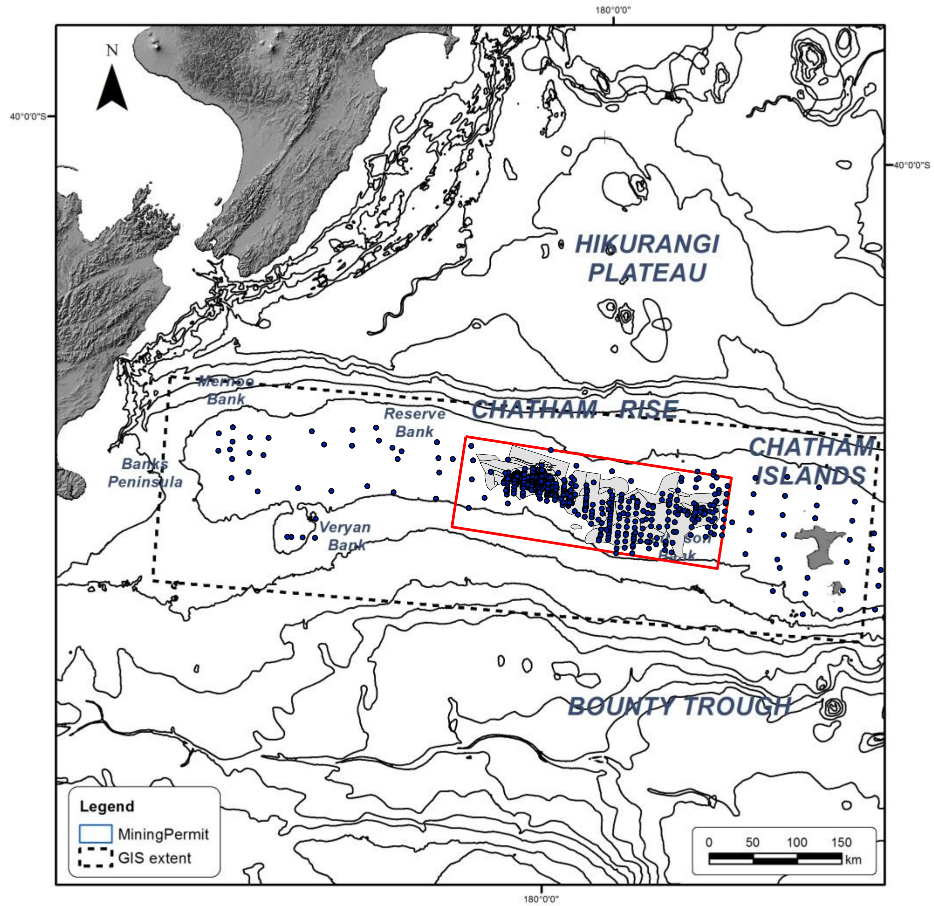


Chatham Rise – Model 2

Fuzzy Logic

Expert-driven model in larger area

- User control on computer modelling
- Flexible and adaptive
- Can work with sparse and incomplete datasets



Model area: 31000 km^2

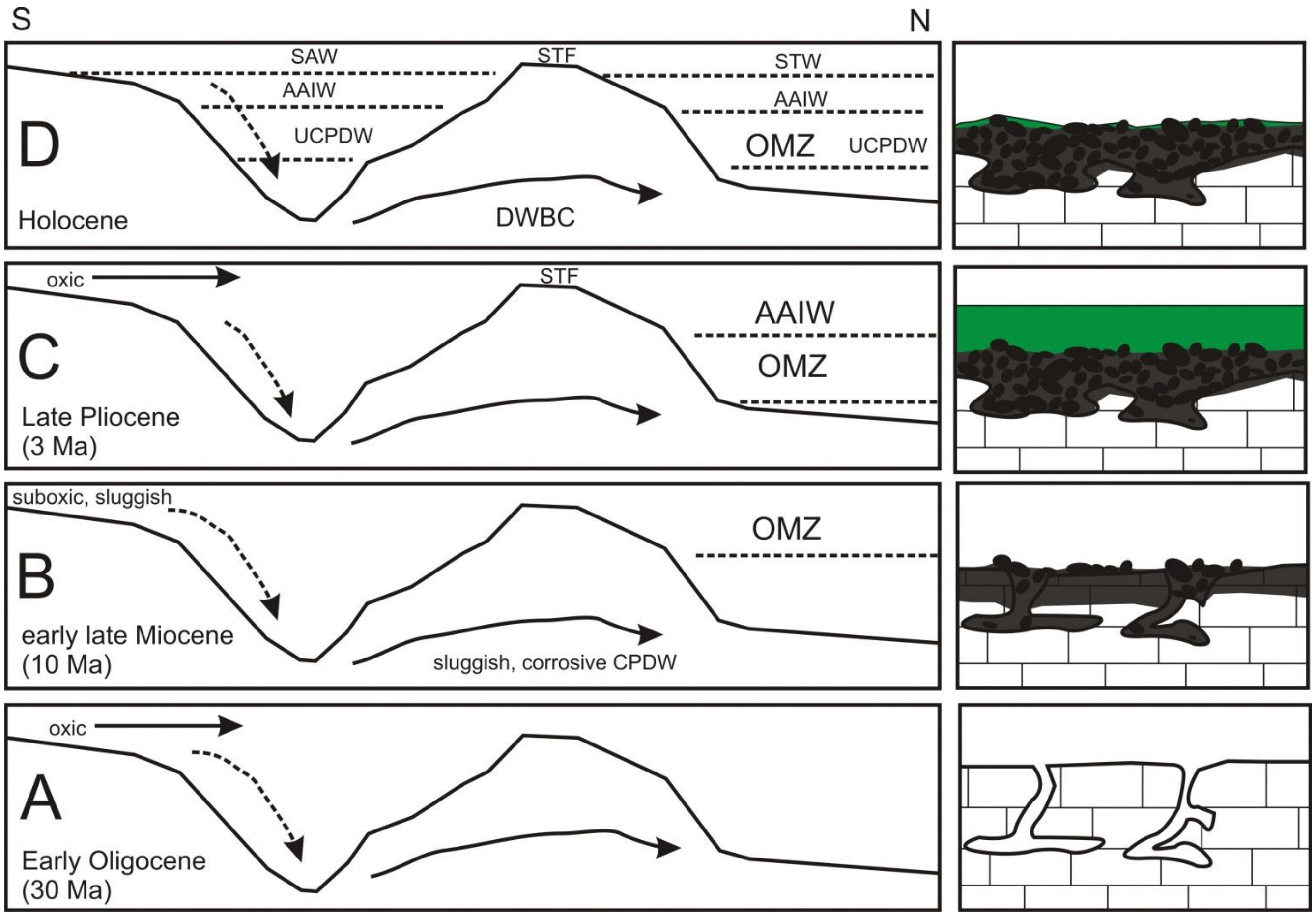
Mineral System Model

Deposition
Concentration of HG rubble and exposure of nodular phosphate

Transport
Hardground formation, focussing by bottom currents

Source
Phosphatisation in suboxic environment

Trap
Oligocene and Miocene chalk



Source – Upwelling and Circulation

Warm East Cape Current

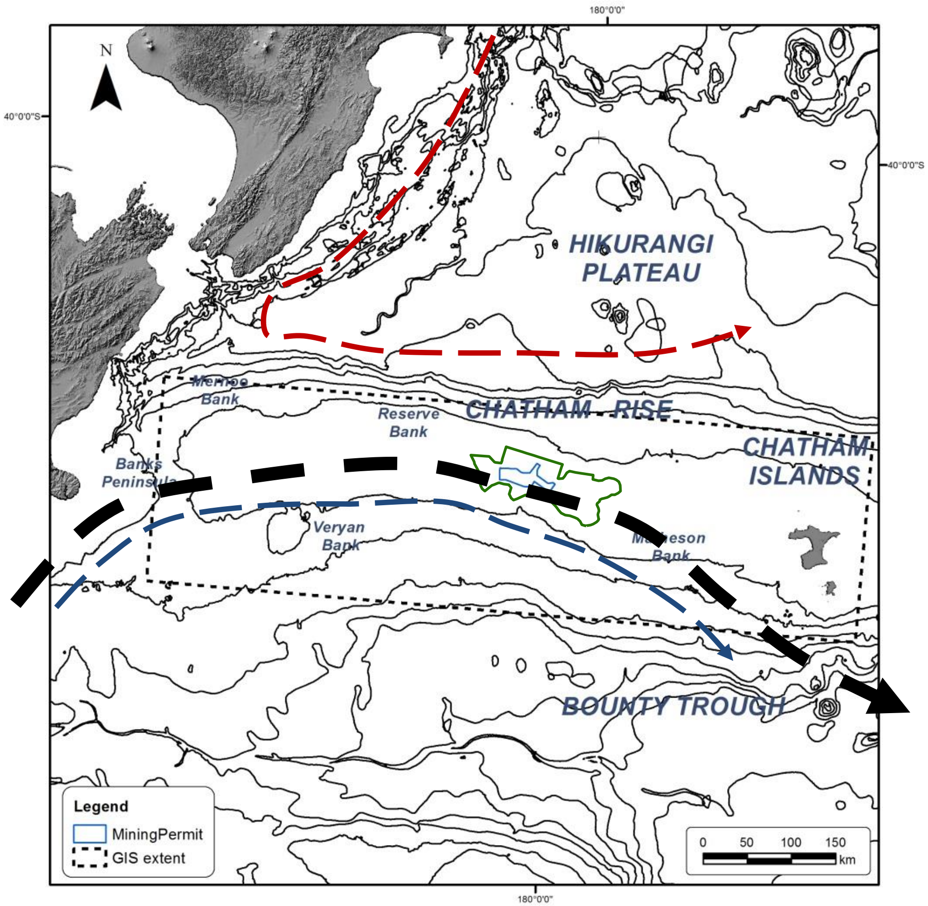
Subtropical Front

Upwelling, organic (phosphate) production

Cold Southland Current

Source:

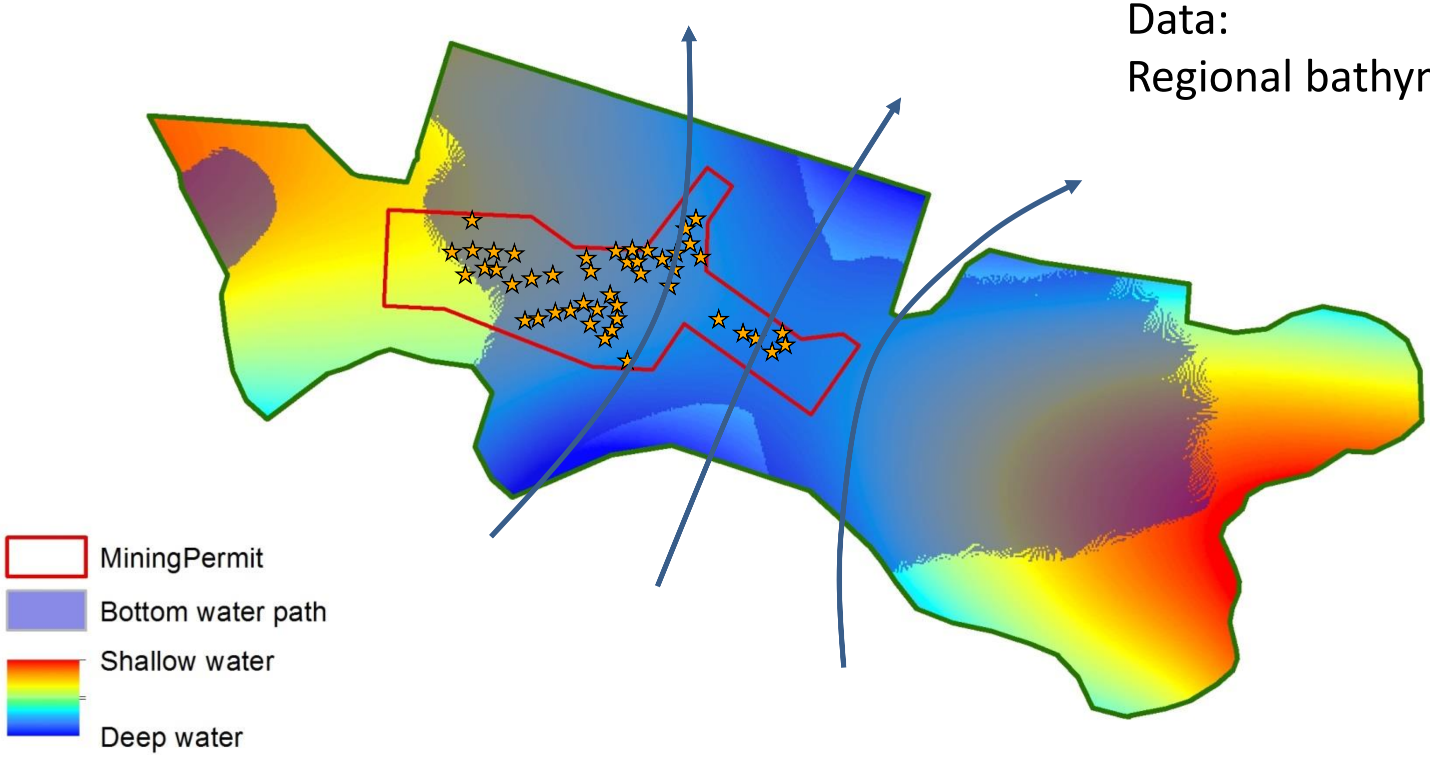
Modern STF with Tasman Gateway opening (E. Oligocene)



Source – watermass movement

Variable	Area	# TPs	W+	Ws+	W-	Ws-	**C**	Cs	**Stud C**
Association with saddle	3980	44	0.46	0.15	-2.21	0.71	**2.7**	0.72	**3.7**

Data:
Regional bathymetry

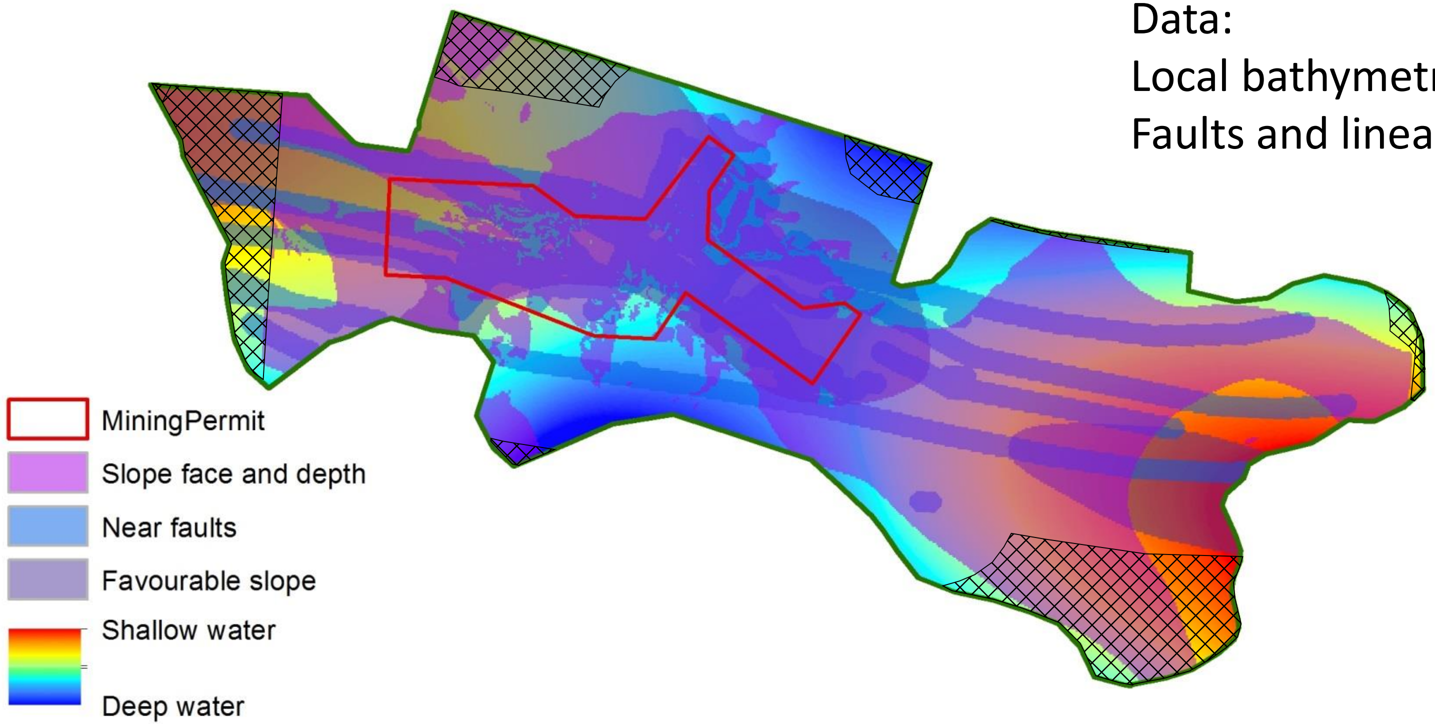


Path – bottom water influence

Variable	Area	# TPs	W+	Ws+	W-	Ws-	**C**	Cs	**Stud C**
Bathymetry and slope aspect	3826	39	0.33	0.16	-0.94	0.38	**1.3**	0.41	**3.1**
Distance from faults	2150	41	0.90	0.16	-1.77	0.45	**2.7**	0.48	**5.6**
Assoc. with gentle slopes	2869	37	0.62	0.17	-1.06	0.33	**1.7**	0.37	**4.5**

No data areas

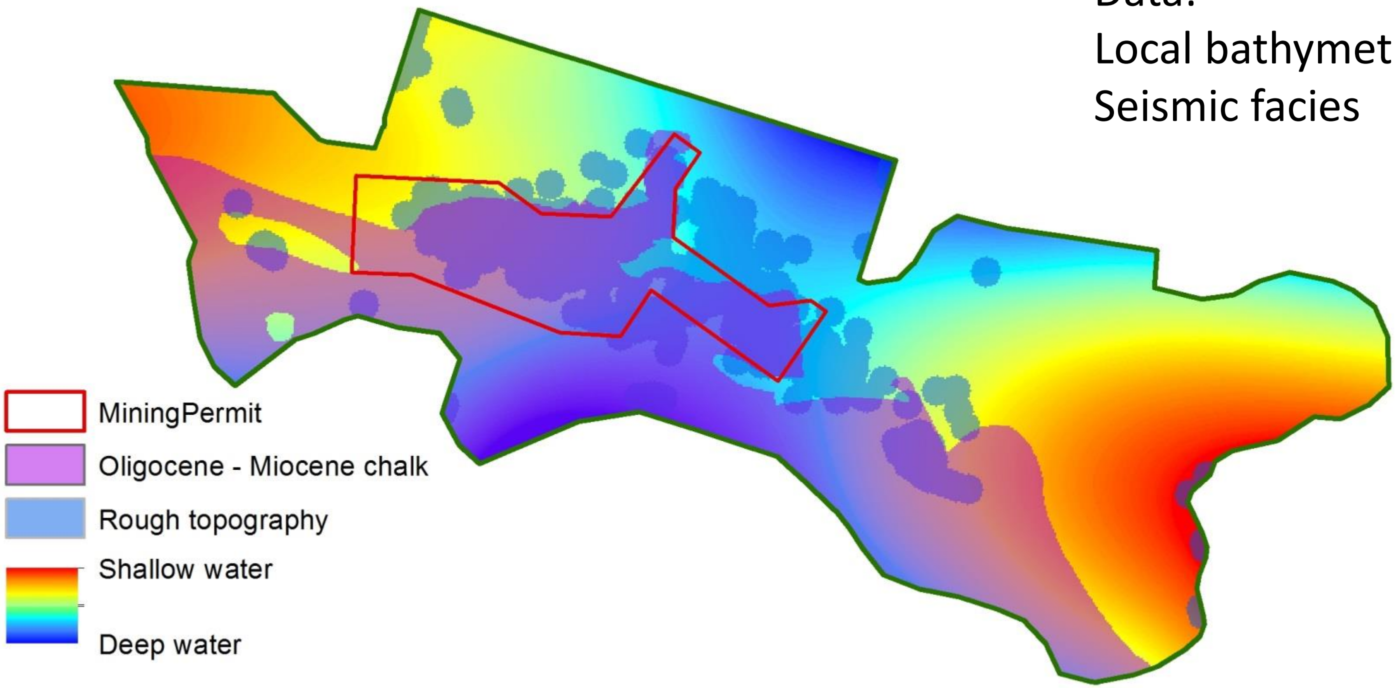
Data:
Local bathymetry
Faults and lineaments



Trap – exposed chalk and hardground

Variable	Area	# TPs	W+	Ws+	W-	Ws-	**C**	Cs	**Stud C**
Associaton with chalk	2632	44	0.89	0.15	-2.63	0.71	**3.5**	0.72	**4.9**
Rough seabed morph.	1388	44	1.56	0.16	-2.91	0.71	**4.5**	0.72	**6.2**

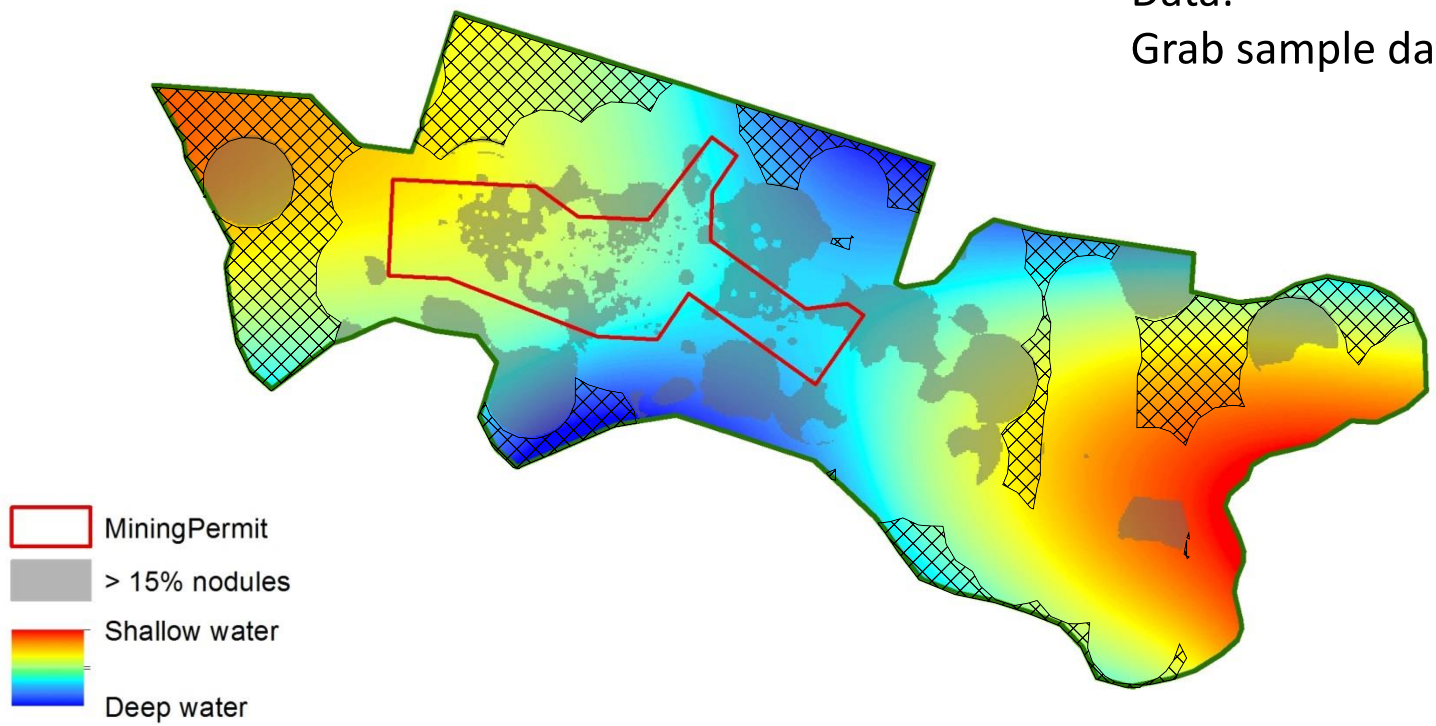
Data:
Local bathymetry
Seismic facies



Deposition – exposure of nodules

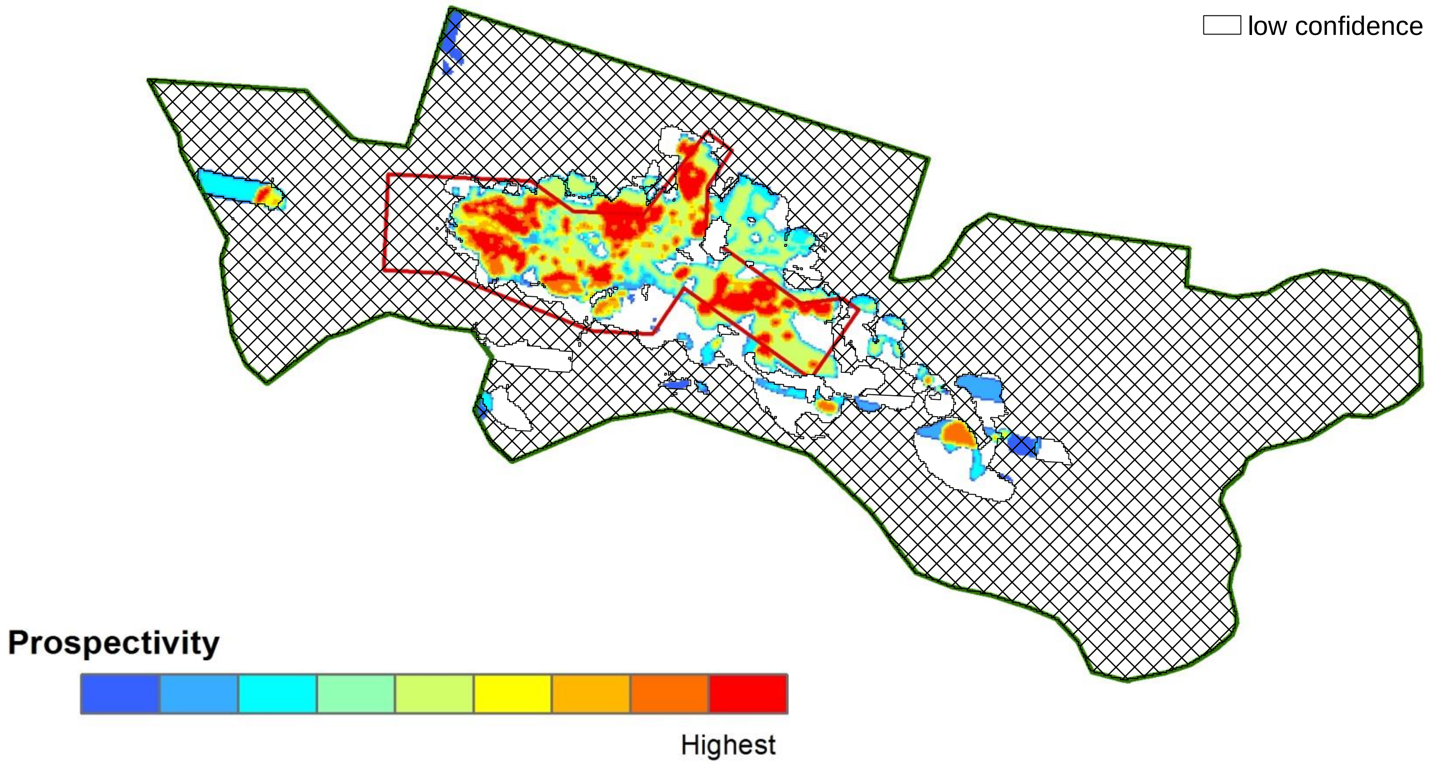
Variable	Area	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C
Nodule abundance	1412	43	1.25	0.16	-2.42	0.58	3.7	0.60	6.1

Data:
Grab sample data

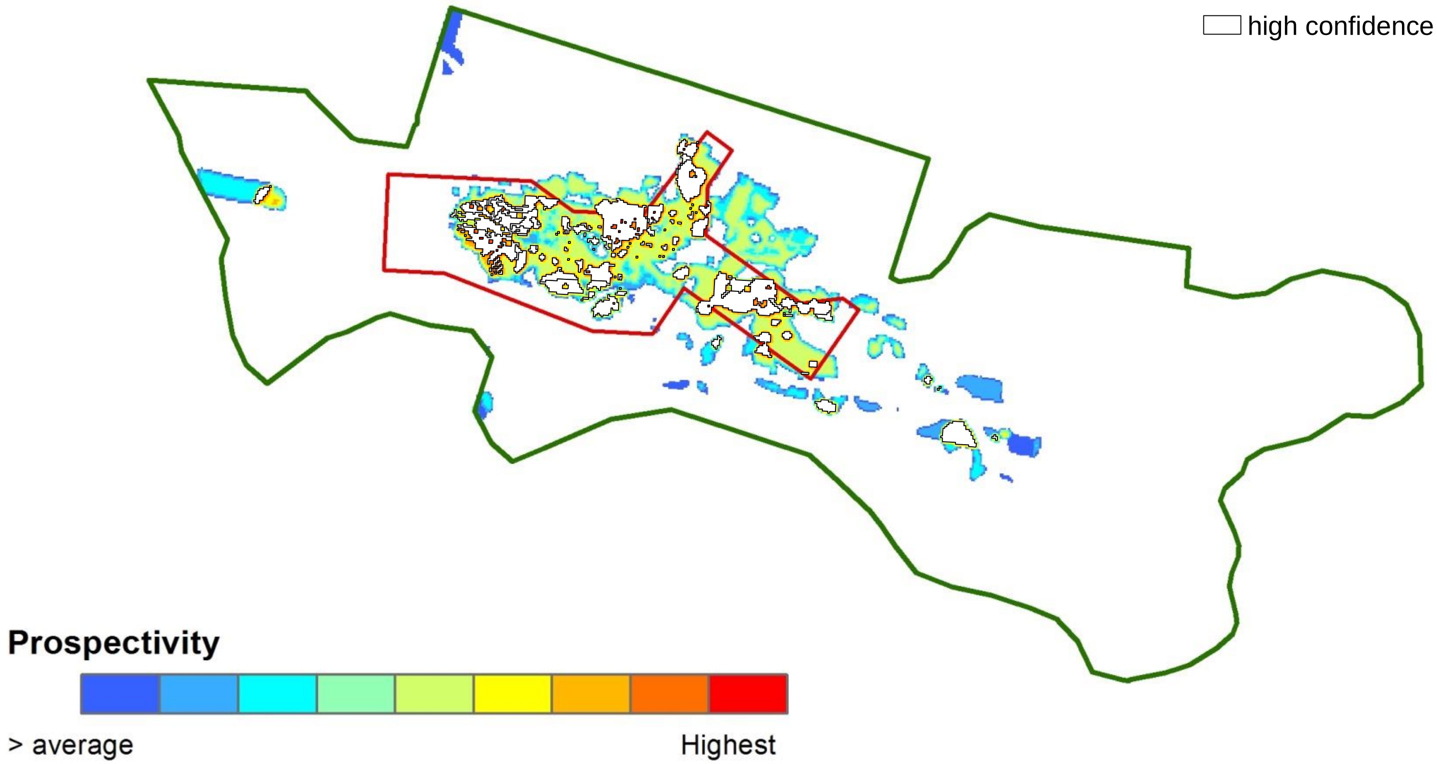


Posterior probability

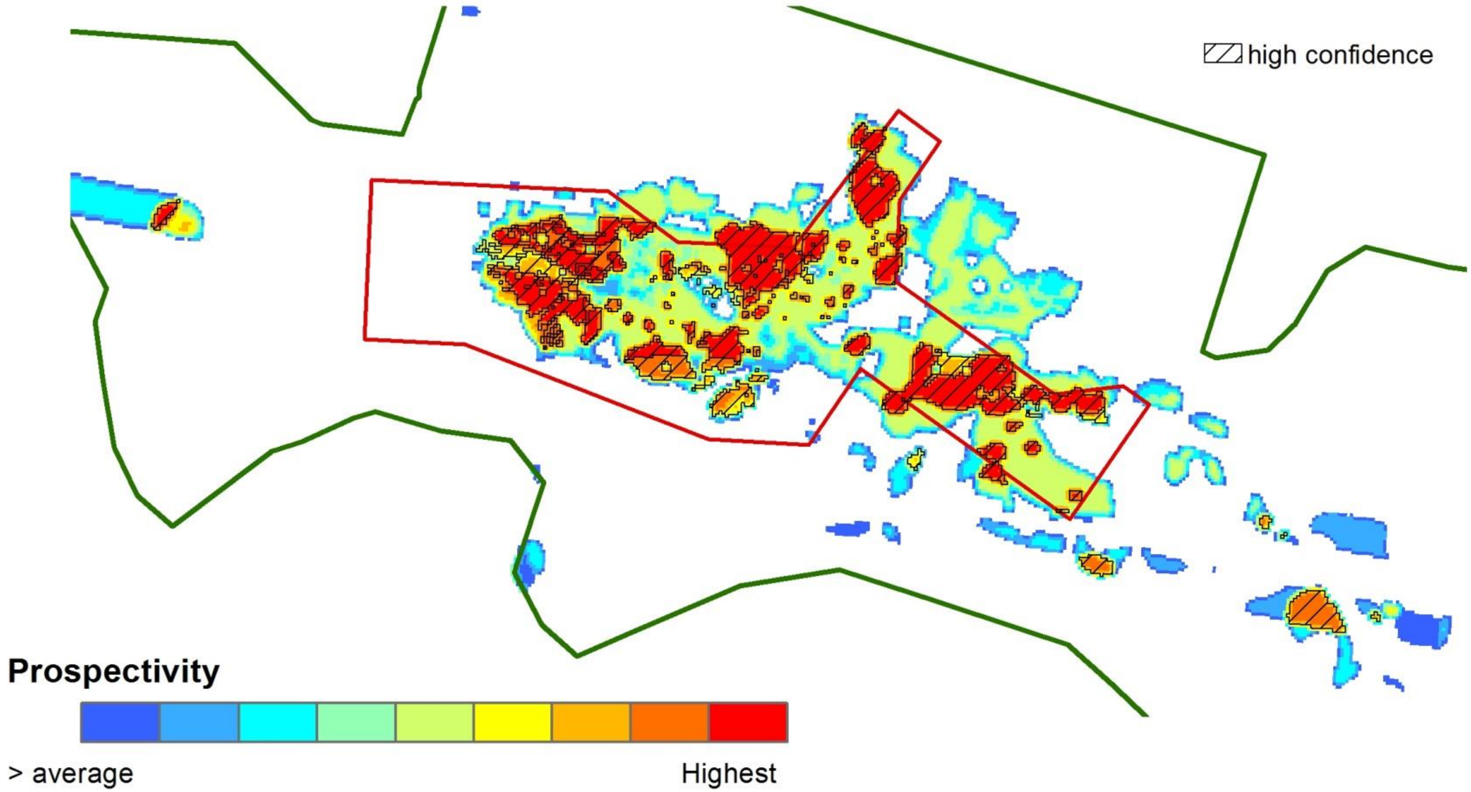
Standard deviation and no data areas used to build confidence map (students T-test)



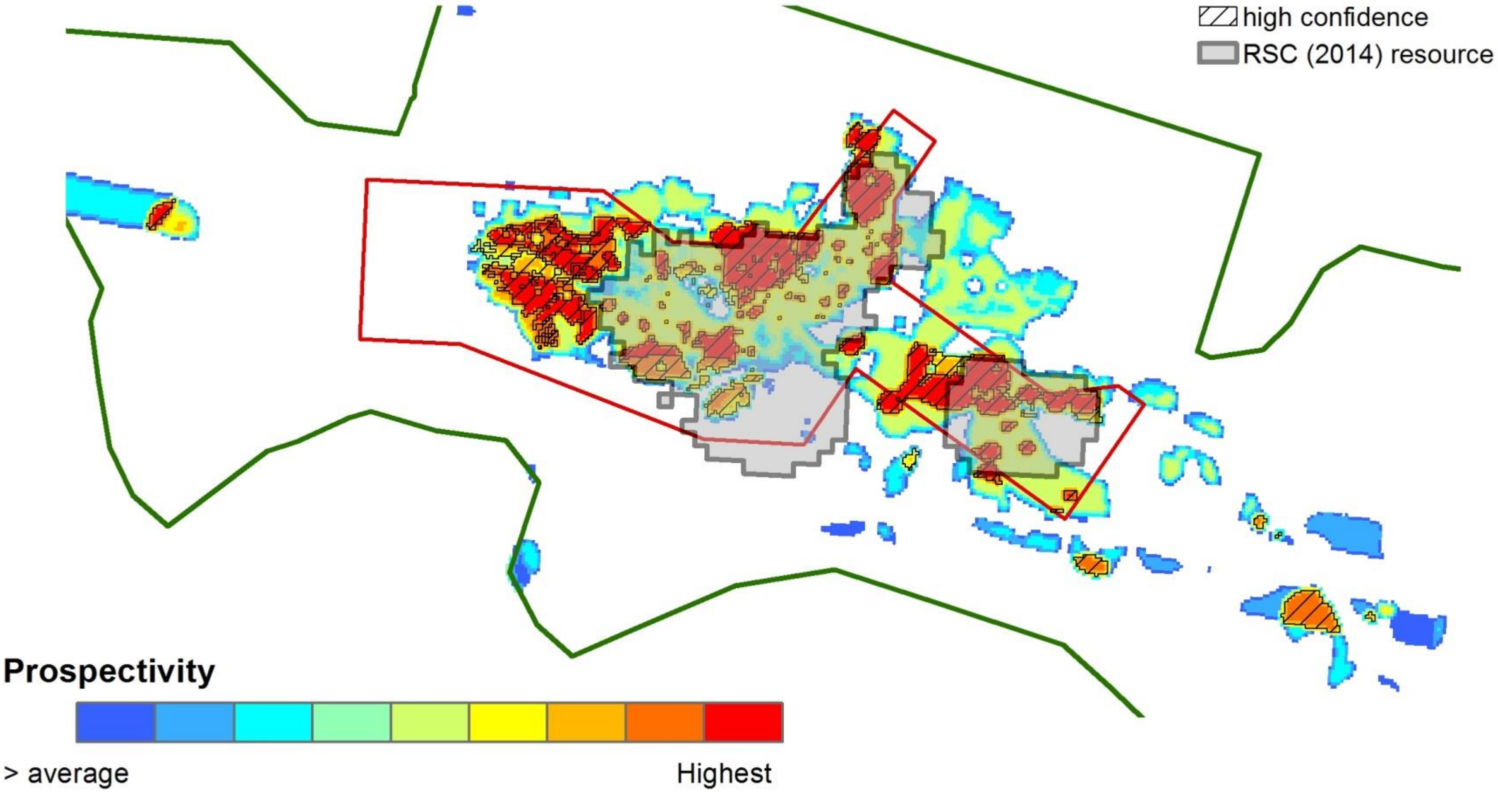
Posterior probability



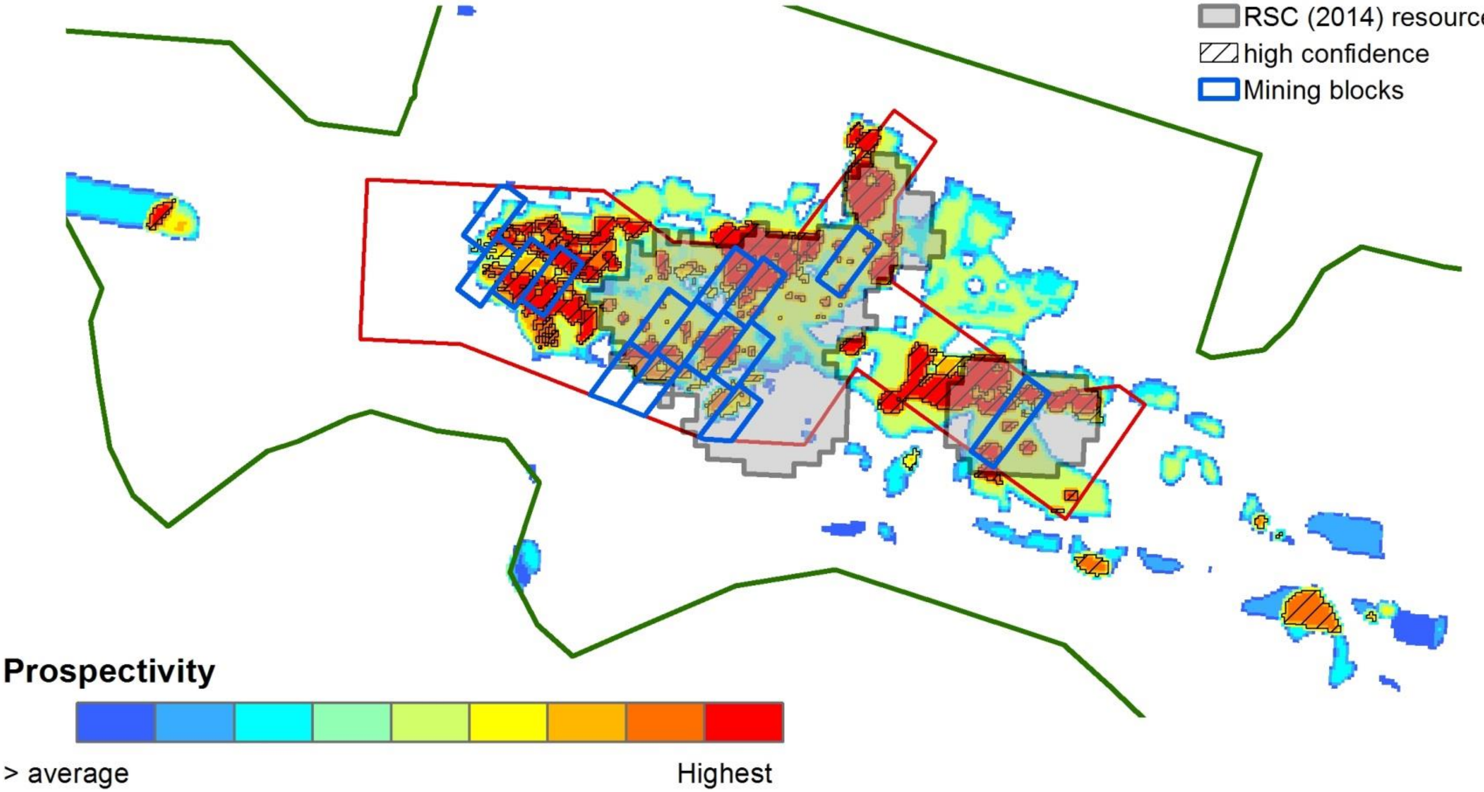
Confidence vs Resource



Confidence vs Resource

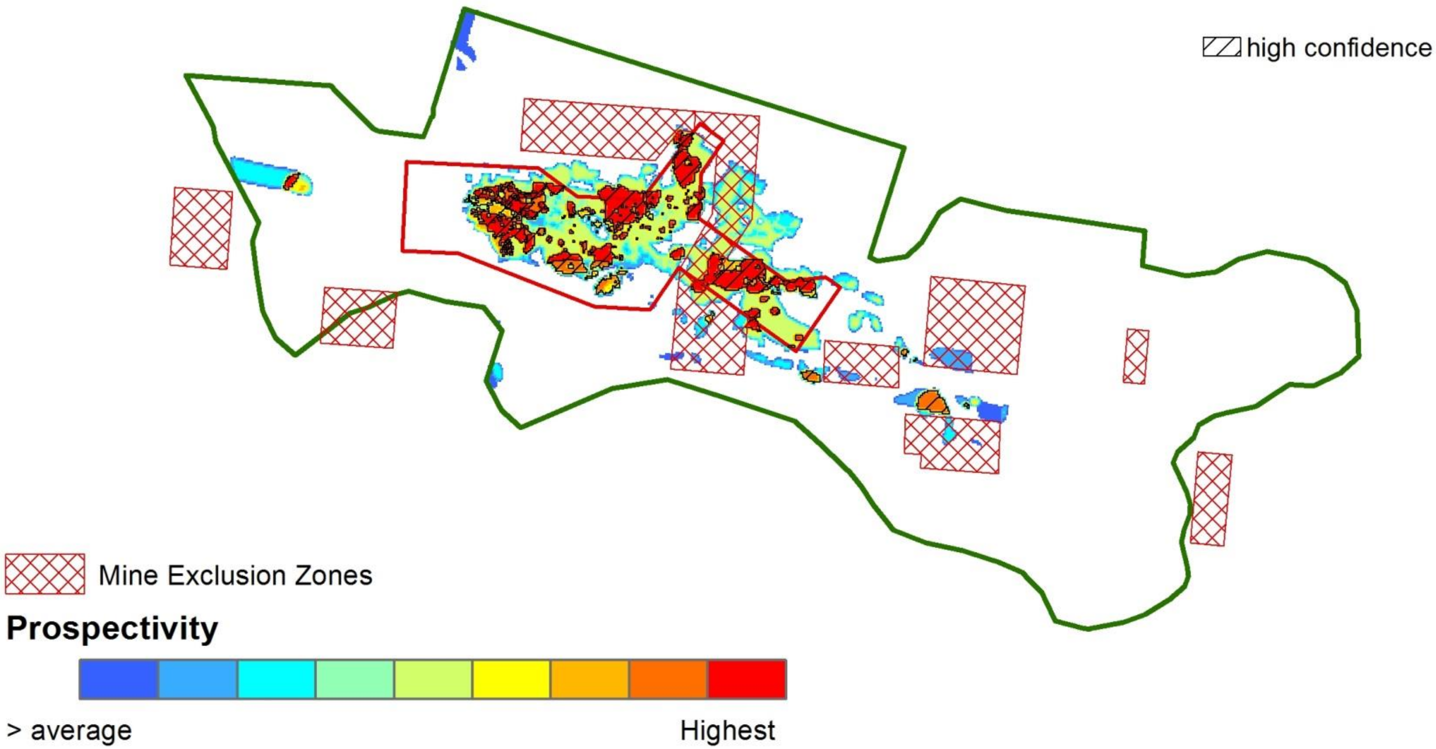


Confidence vs Resource



Future planning

Future exploration guided by model uncertainty and limitations set by environmental considerations



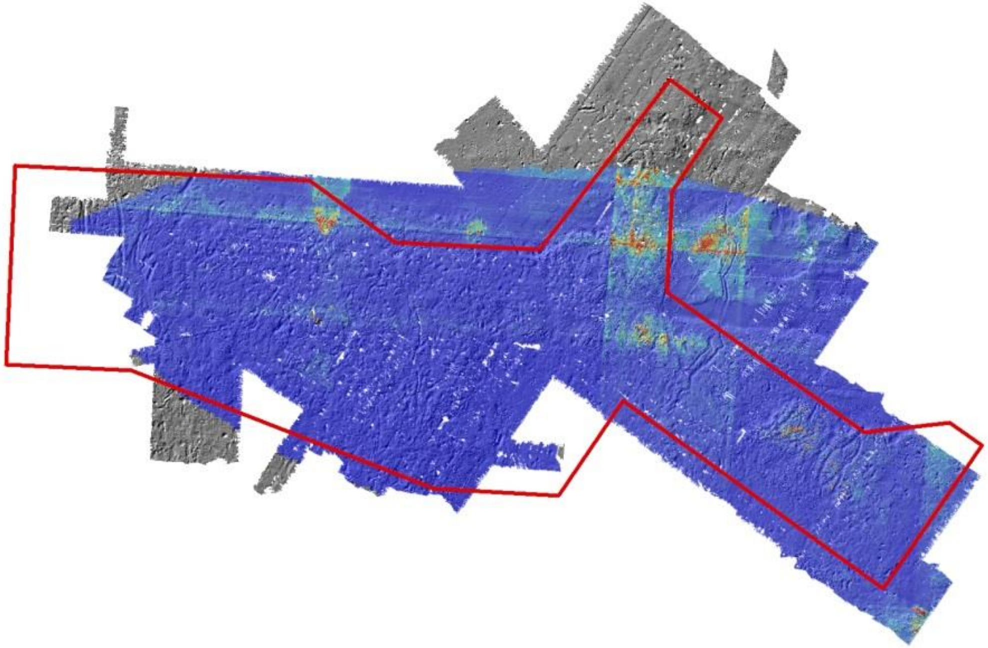
Fuzzy Logic Modelling

Expert input guided by WoE modelling results

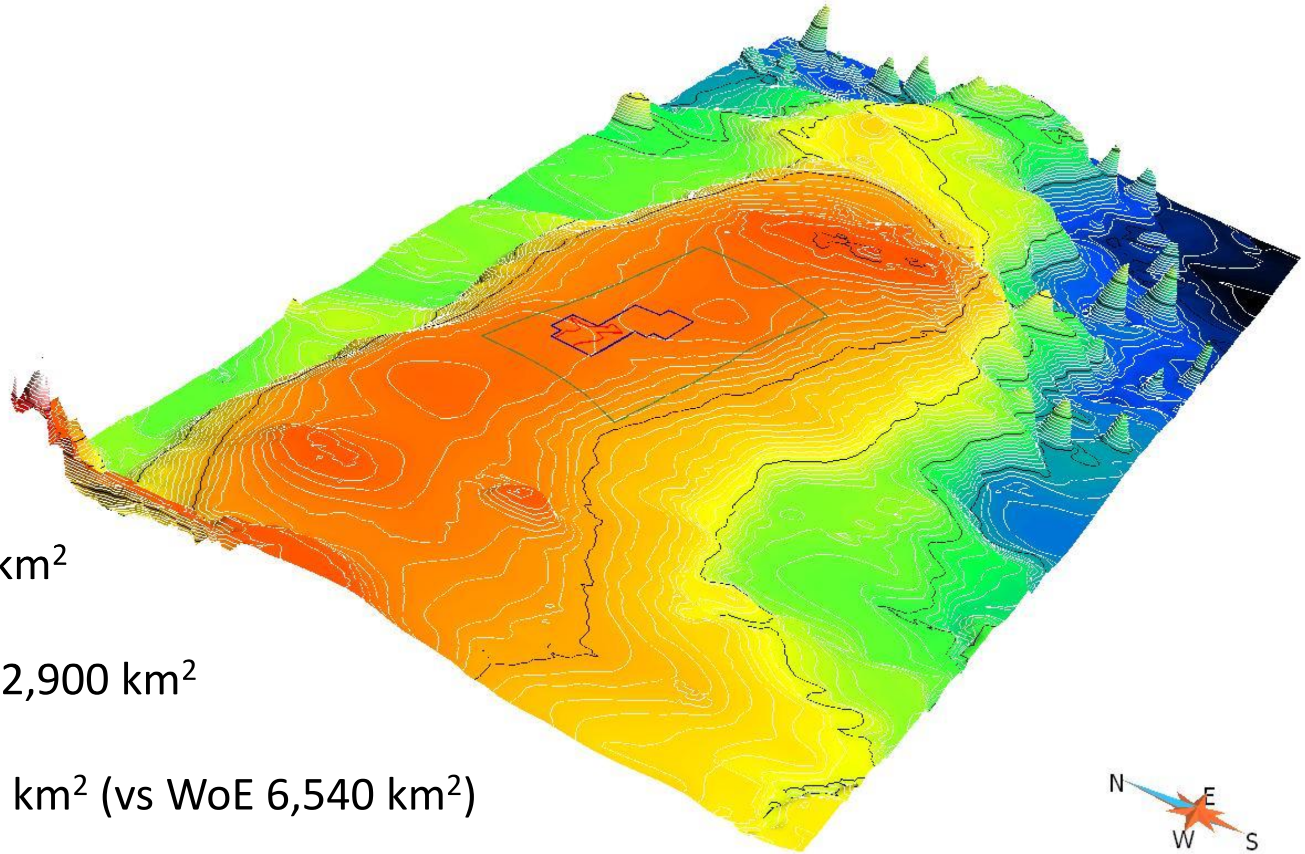
	Variable	C	Stud C	Fuzzy IN	Fuzzy OUT	Fuzzy NODATA
*	Association with saddle	2.7	3.7	**0.7**	**0.3**	
*	Bathymetry and slope aspect	1.3	3.1	**0.7**	**0.3**	
(*)	Distance from faults	2.7	5.6	**0.7**	**0.5**	**0.5**
*	Assoc. with gentle slopes	1.7	4.5	**0.8**	**0.1**	
	Associaton with chalk	3.5	4.9	**0.5 - 0.8**	**0.01 - 0.1**	
*	Rough seabed morph.	4.5	6.2			
	Nodule abundance	3.7	6.1	**0.8**	**0.5**	**0.5**

* Associated with bathymetry mapping

as is NIWA predictive habitat modelling
Epibenthic community *h*
(*Goniocorella dumosa*)



Greater study area

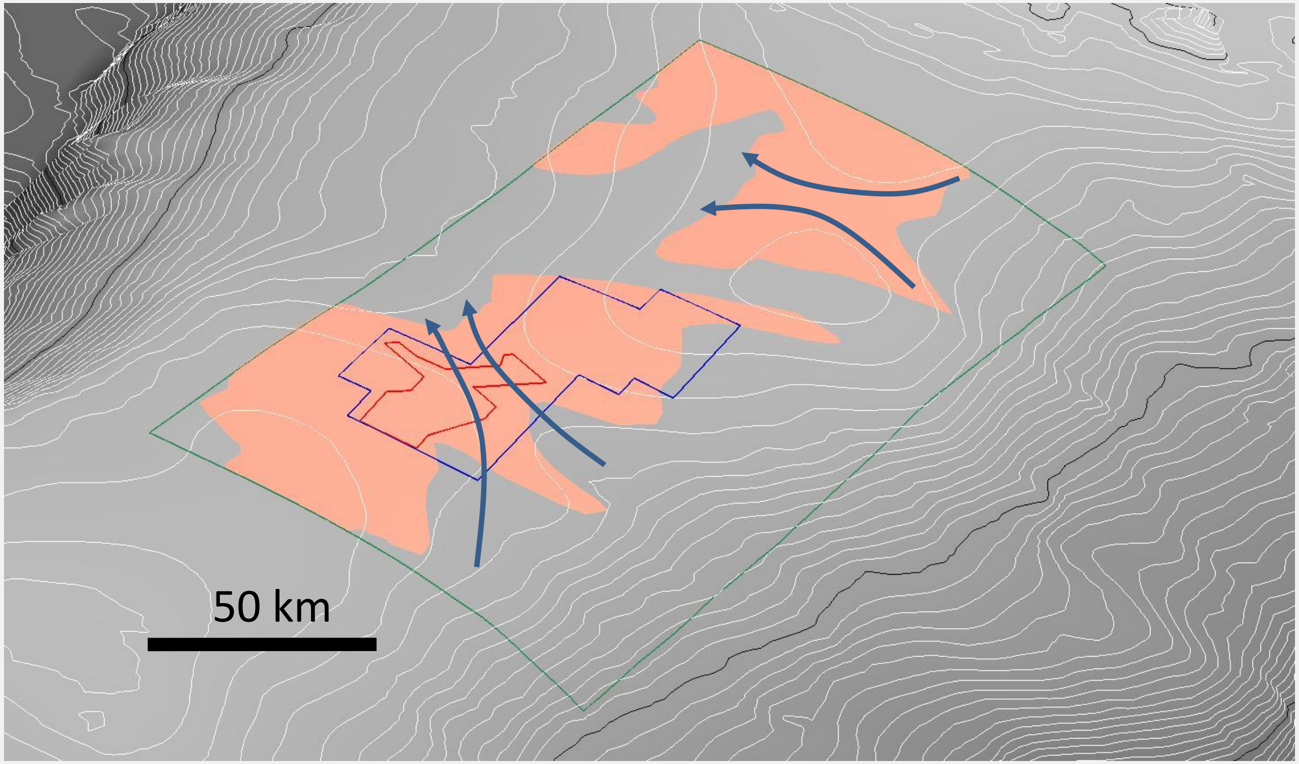


Mining license: 820 km^2

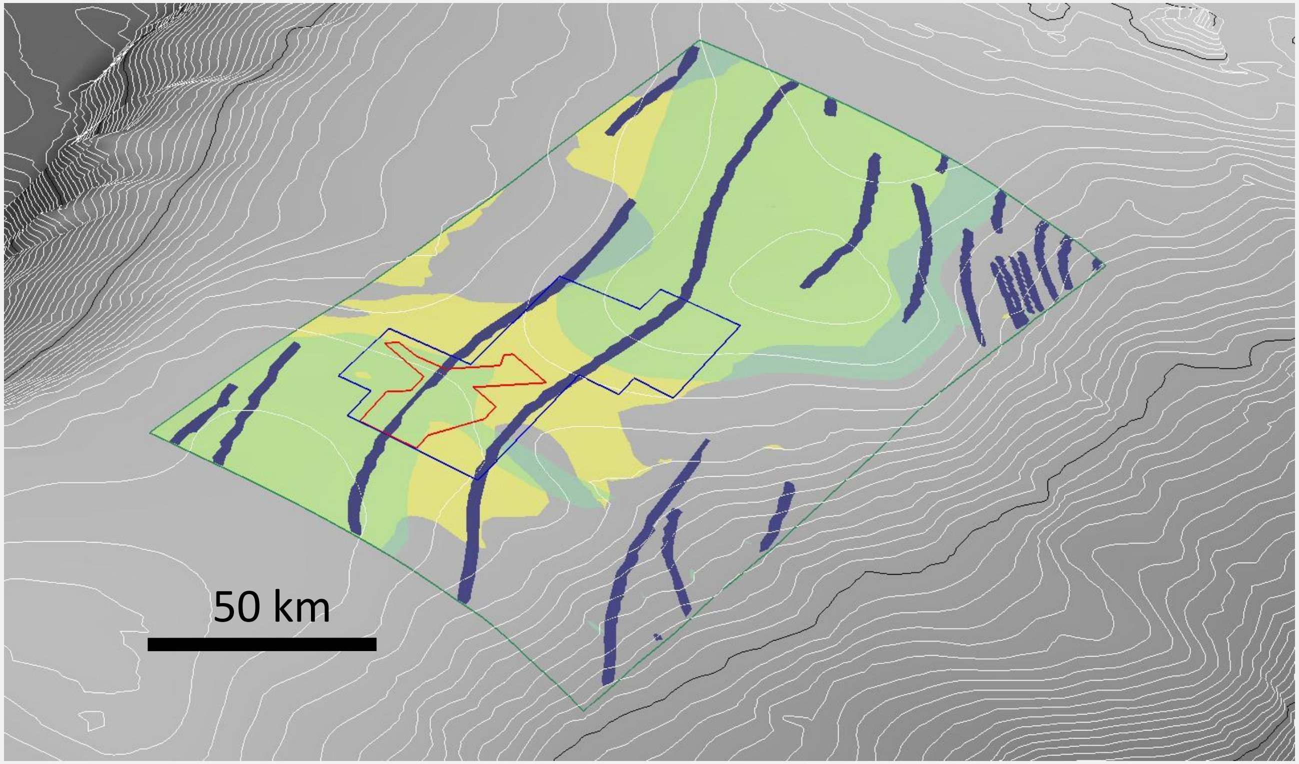
Prospecting license: 2,900 km^2

Fuzzy model: 31,000 km^2 (vs WoE 6,540 km^2)

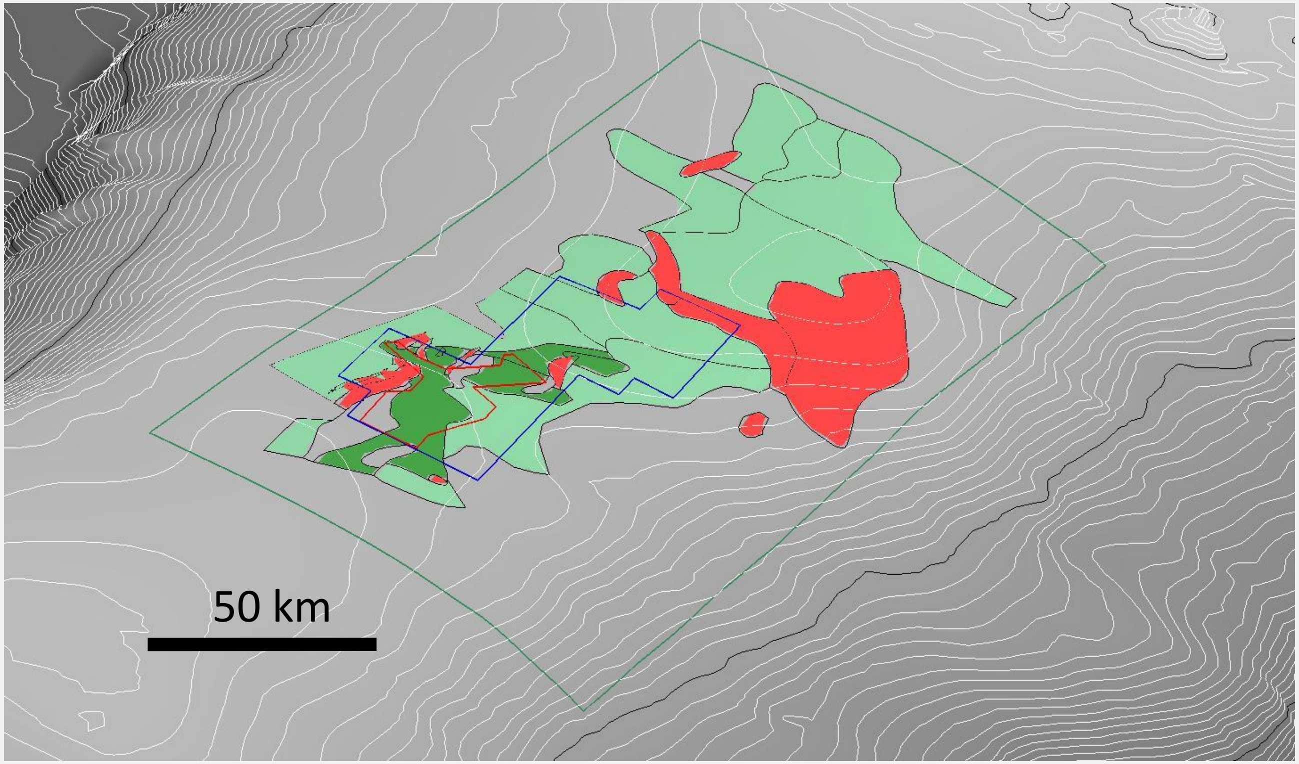
Source – several high flux areas?



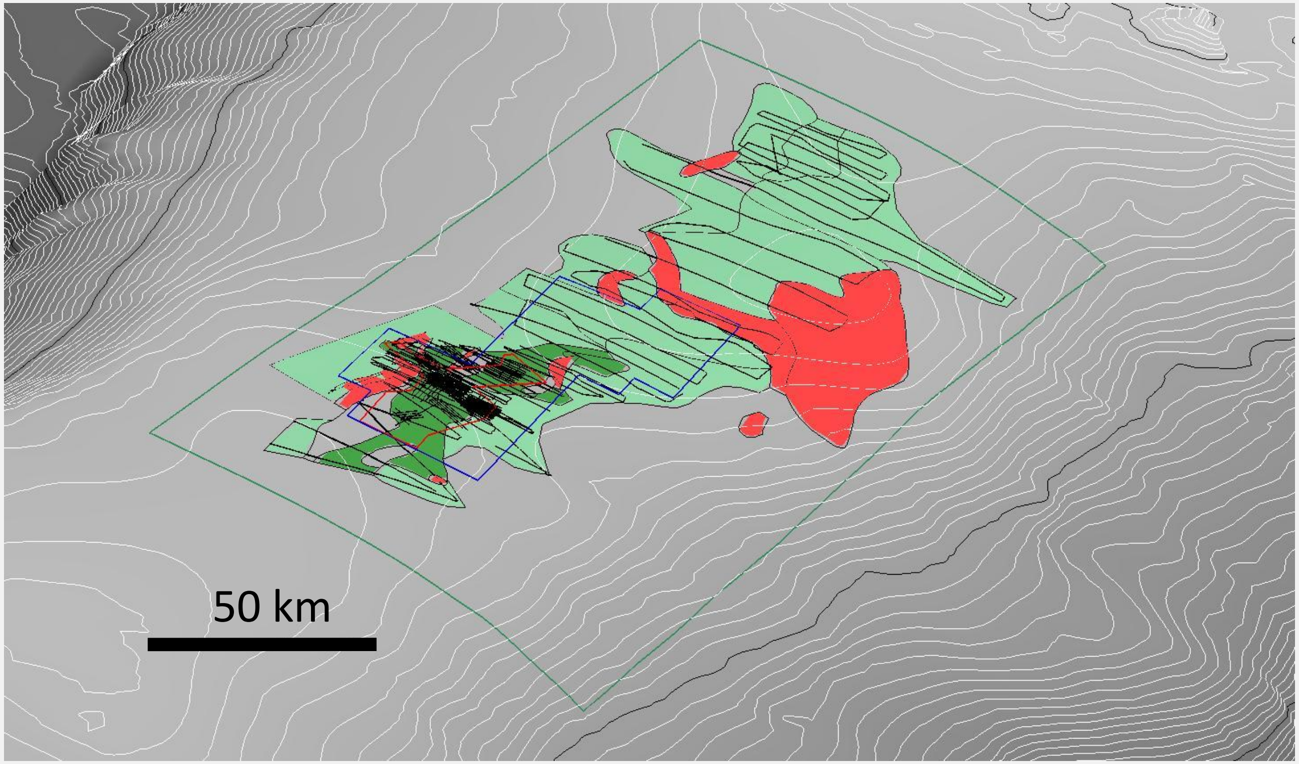
Pathways – regional scale



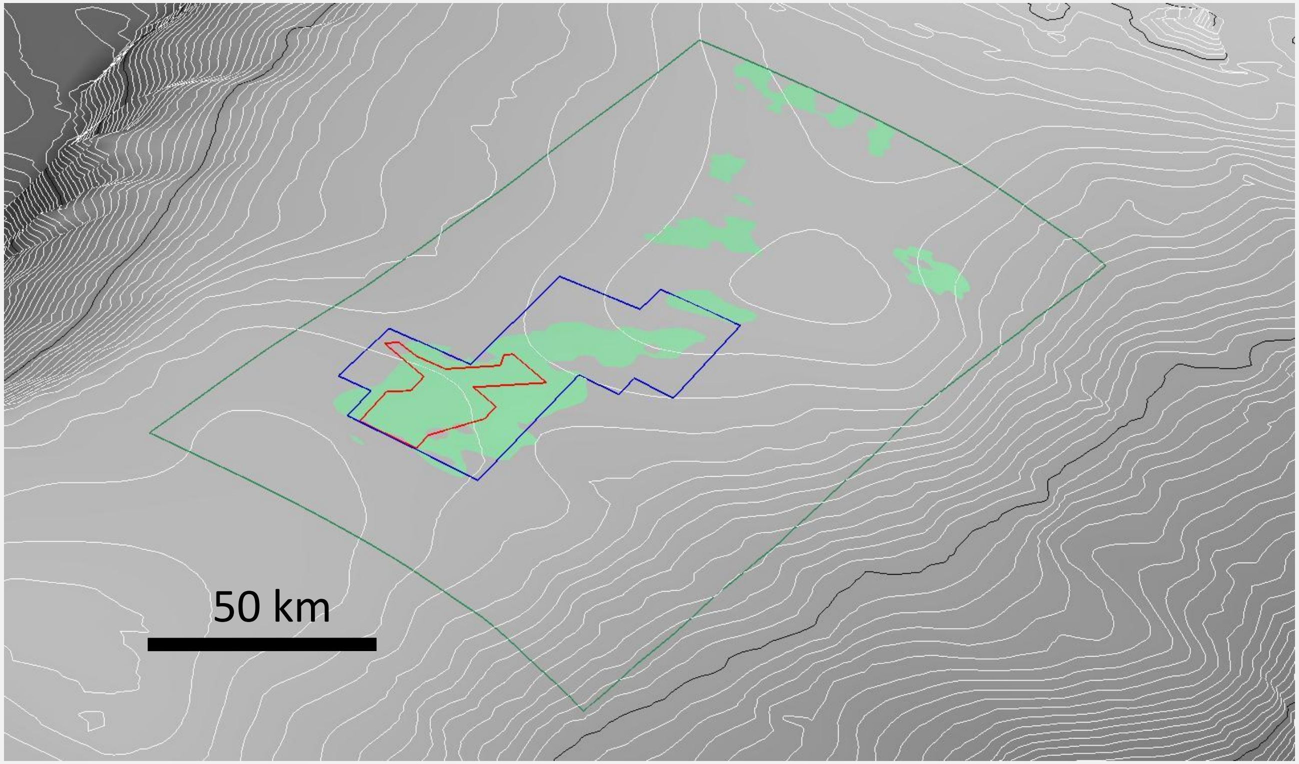
Trap – chalk facies distribution



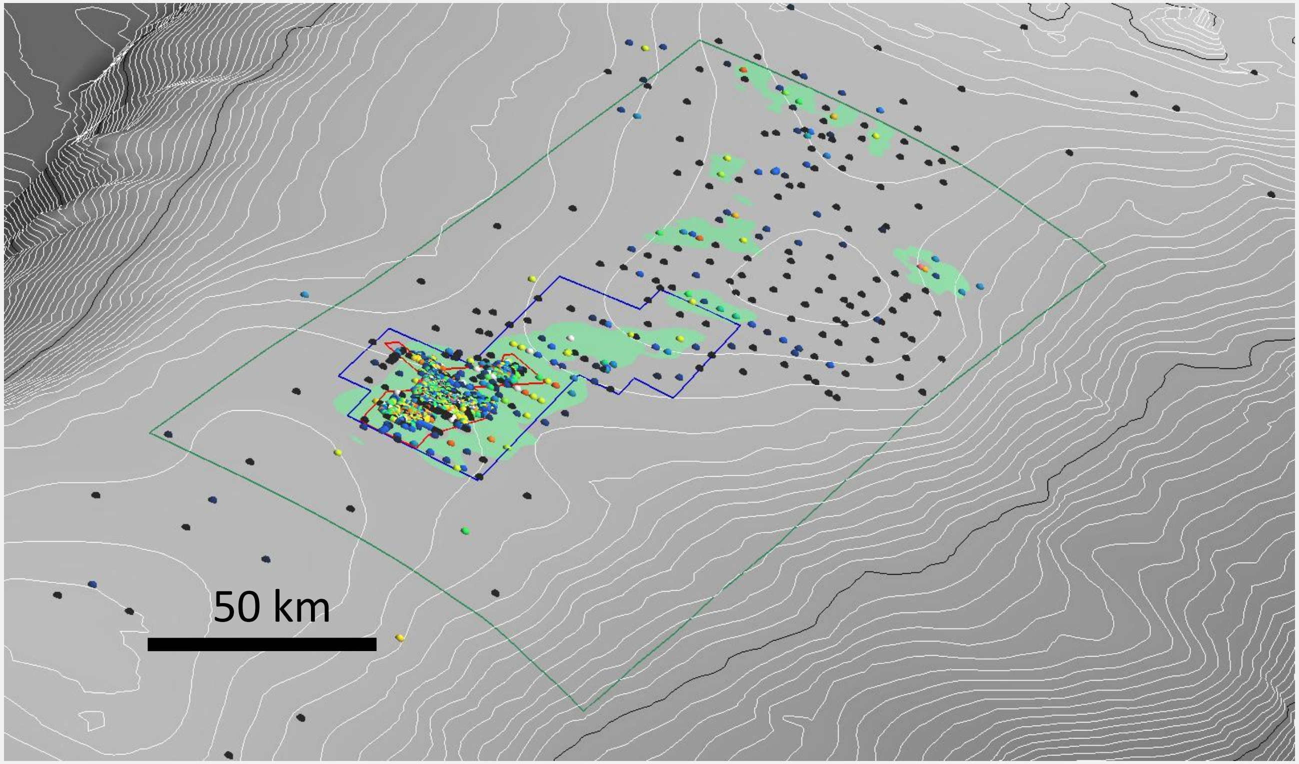
Trap



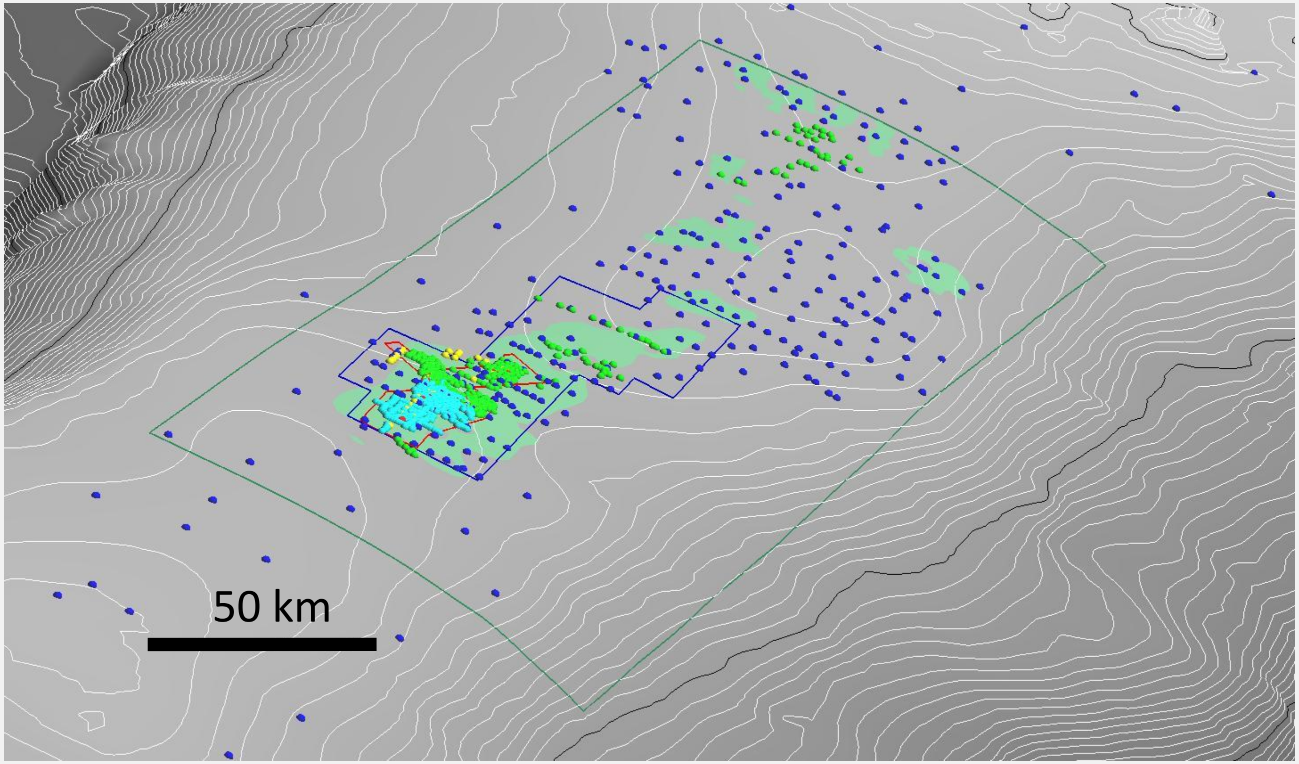
Deposition



Deposition and sample density

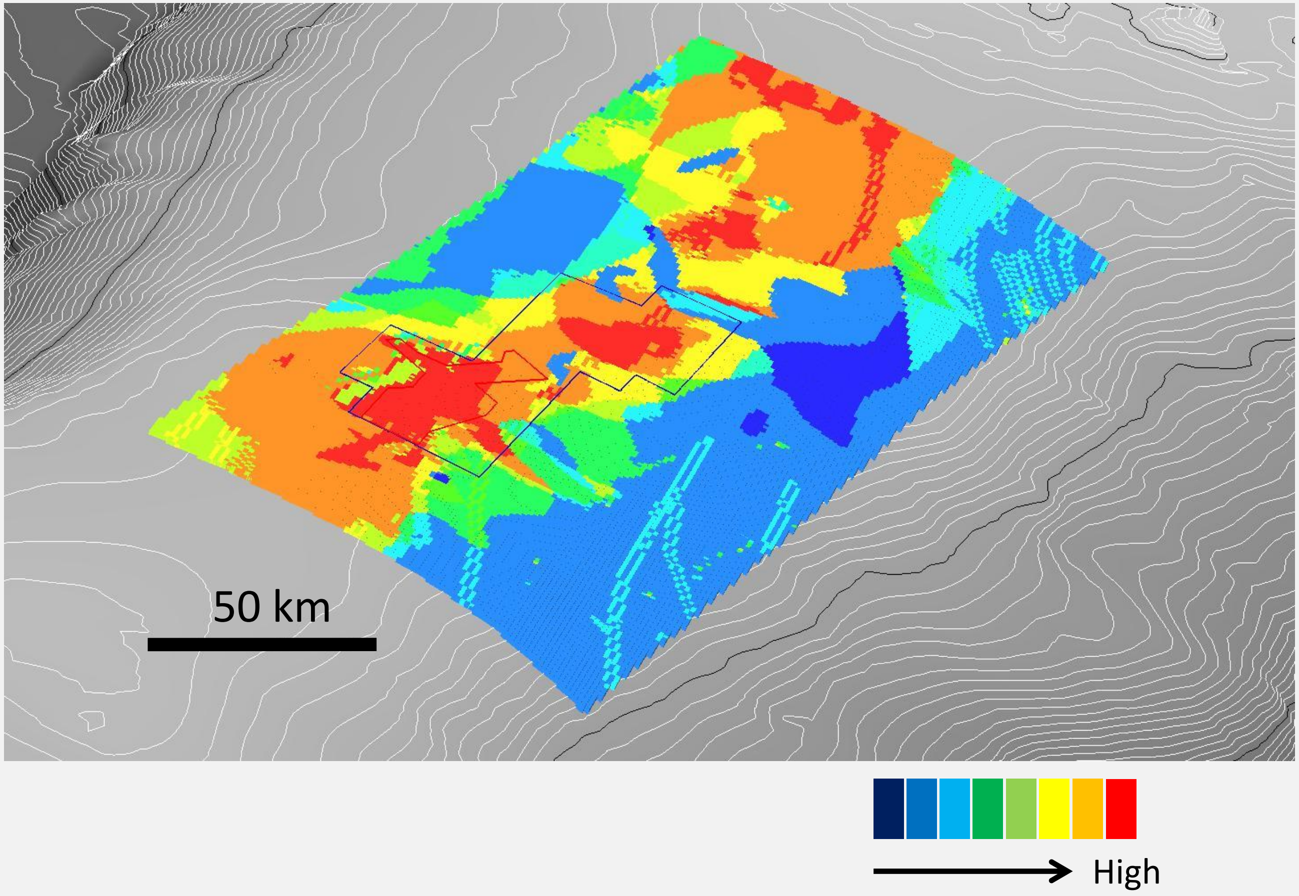


Deposition and sample type



Fuzzy prospectivity

Several areas of high prospectivity (red)

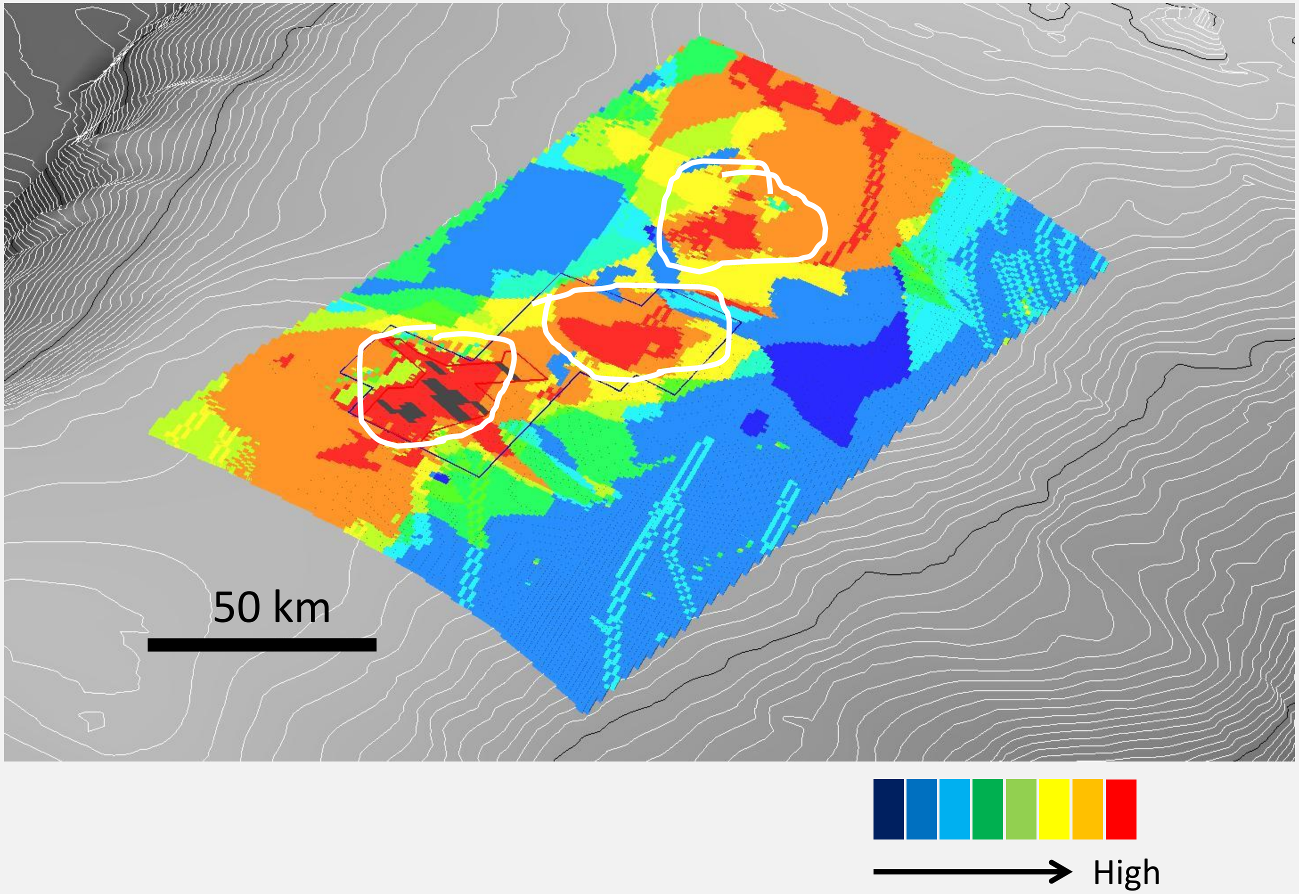


Mining Potential

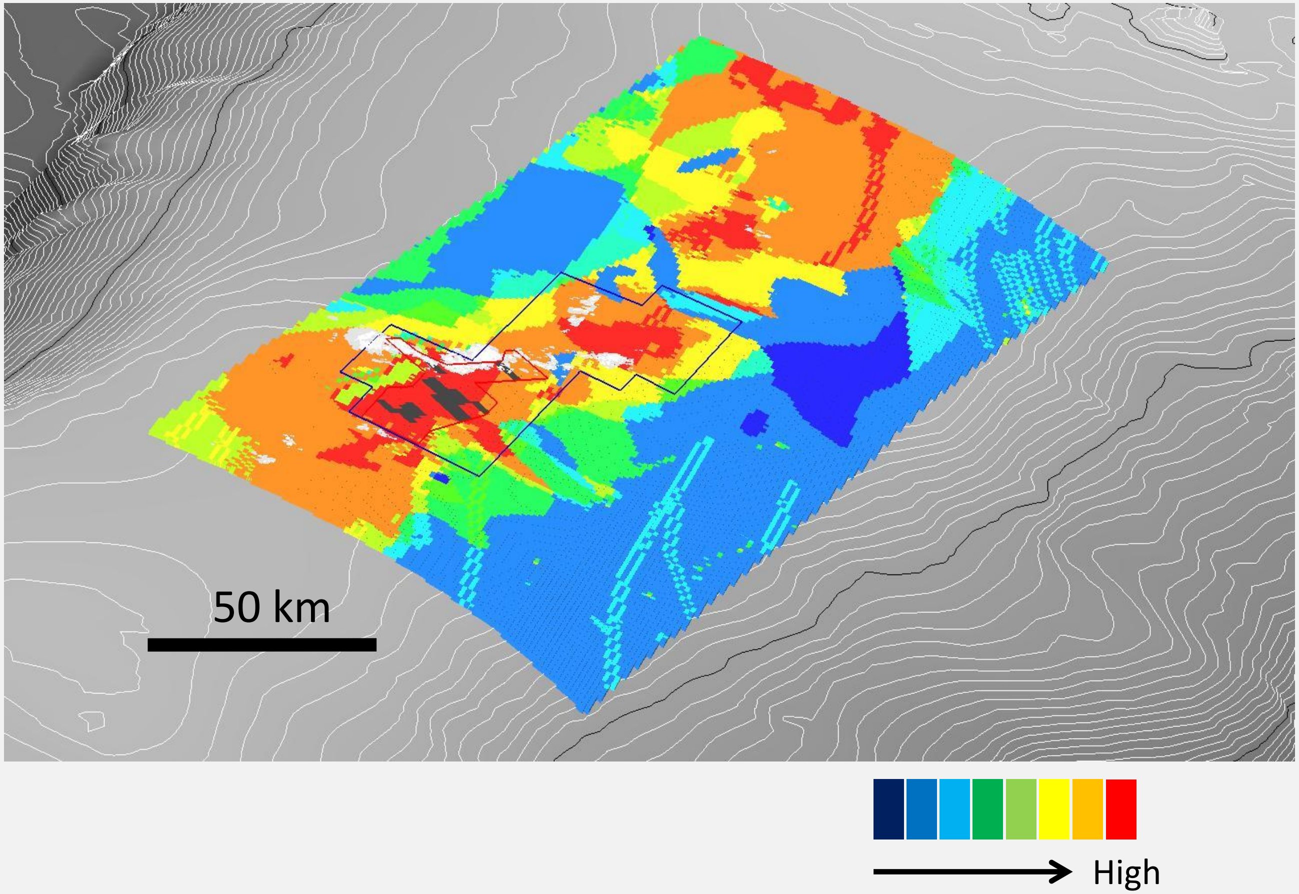
450 km² mined over 15 year period (MLA is 820 km²).

Additional 600 km² mined over 20 year period

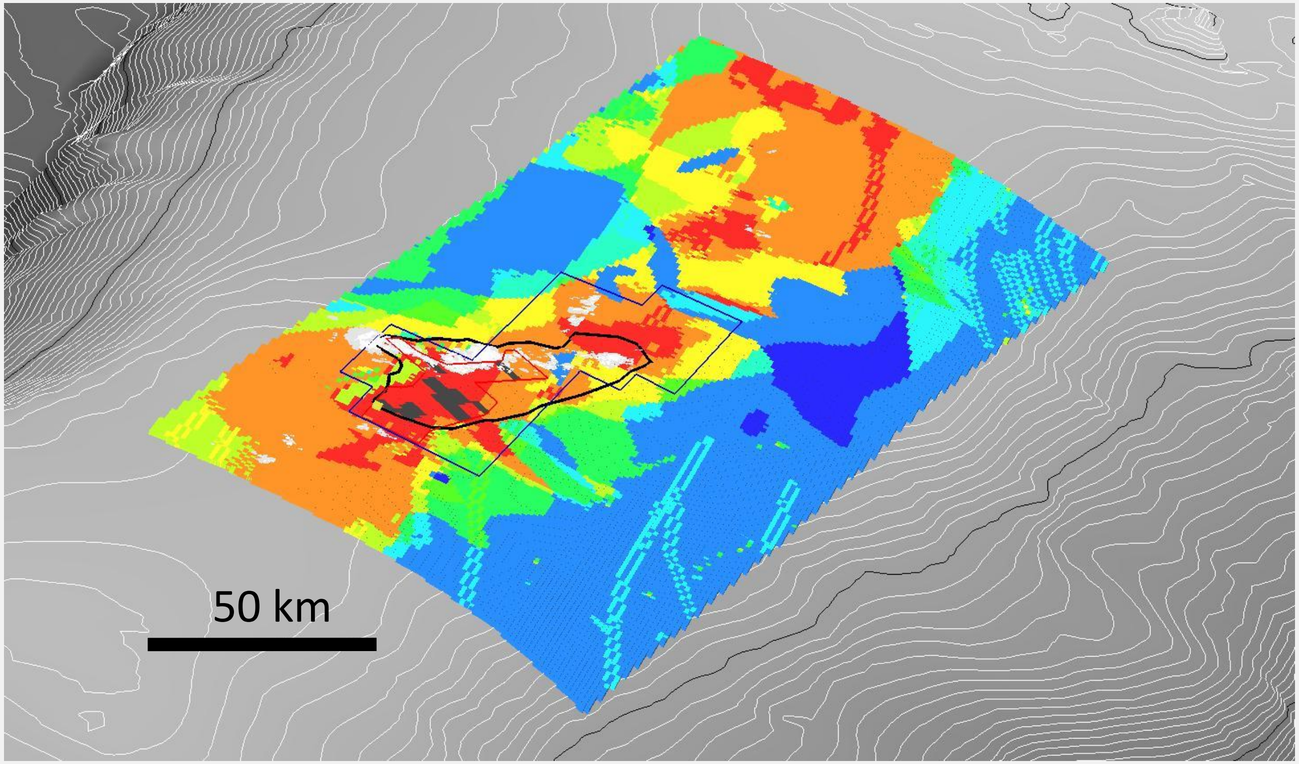
Other areas?

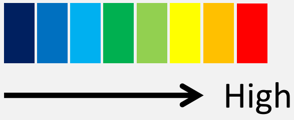


Predicted coral distribution



Effective limit of data





Conclusions

- WoE modelling advantages over resource modelling:

  - Multiple types of data
  - establishment of no data regions and statistics
  - wider distributed targets.

  The combination can guide mine planning and where additional data is needed.

- Fuzzy logic modelling is a planning tool.

- Multibeam bathymetry is cheap and nonintrusive, and
  - delivers > 60% of the model data.
  - is used for environmental modelling,

  Planning for mineral exploration and environmental surveys can be done in unison.

Thank you

- Robin Falconer, Hermann Kudrass
- Greg Partington, Michelle Stokes, Campbell McKenzie
- Scott Nodder, Ashley Rowden, Julia Hall

Kenex
Creating opportunities in the spatial world