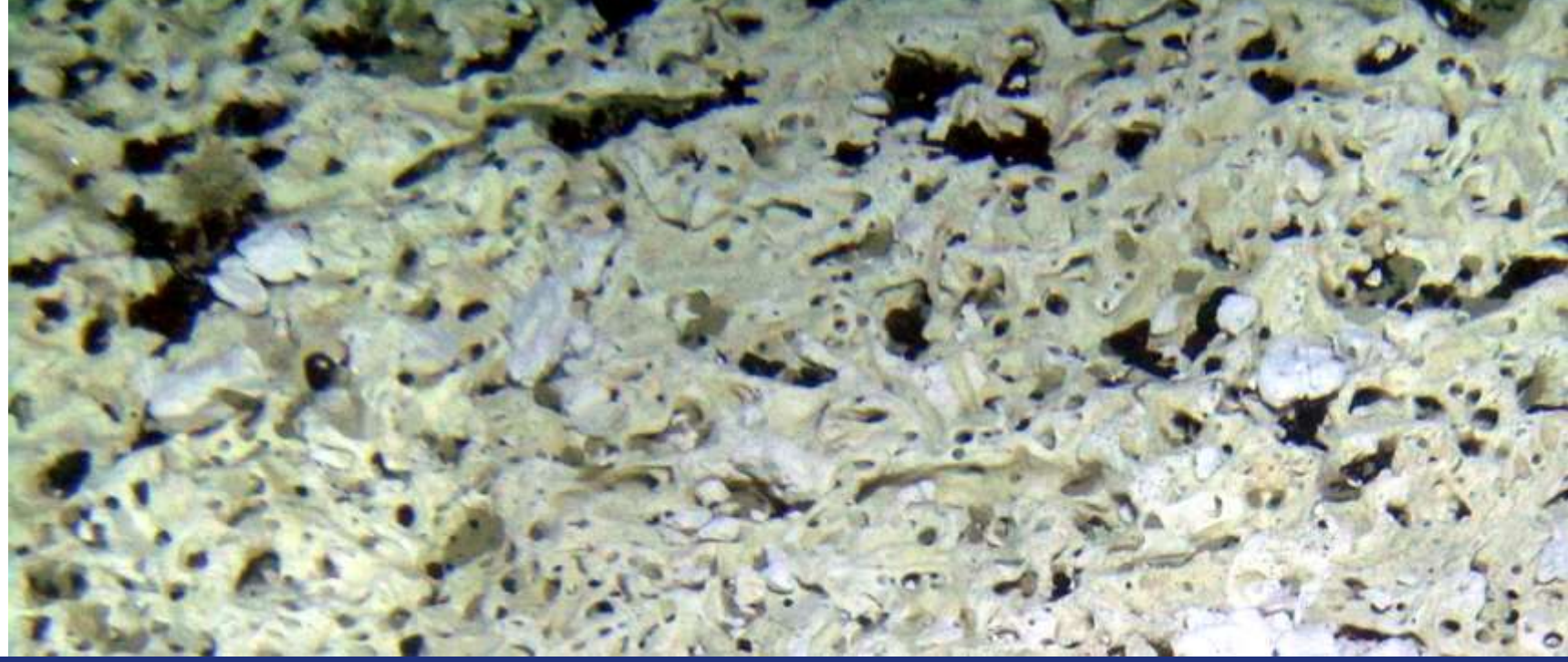


New Insights into the Origin and Distribution of Phosphate Deposits on the Chatham Rise

Kenex
Creating opportunities in the spatial world

Simon HH Nielsen
Kenex, Ltd.

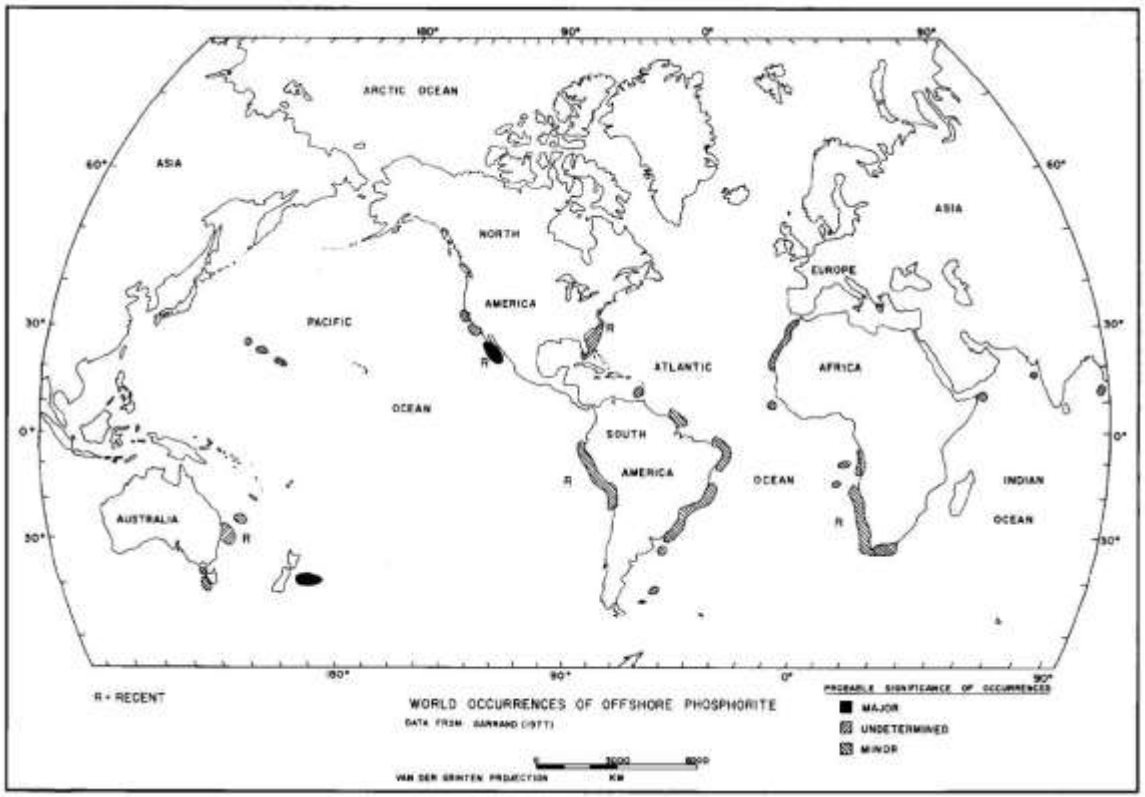
26th IAGS Conference, Rotorua, New Zealand

Outline

- Chatham Rise geology and paleoceanography
- Deposit characteristics:
  - Nodule shape and texture
  - Geochemistry
- Conclusions
  - Are there signs of multiple phosphatisation events on the Rise?

Kenex
Creating opportunities in the spatial world

World Class Phosphate



Mullich & Rasch 1985

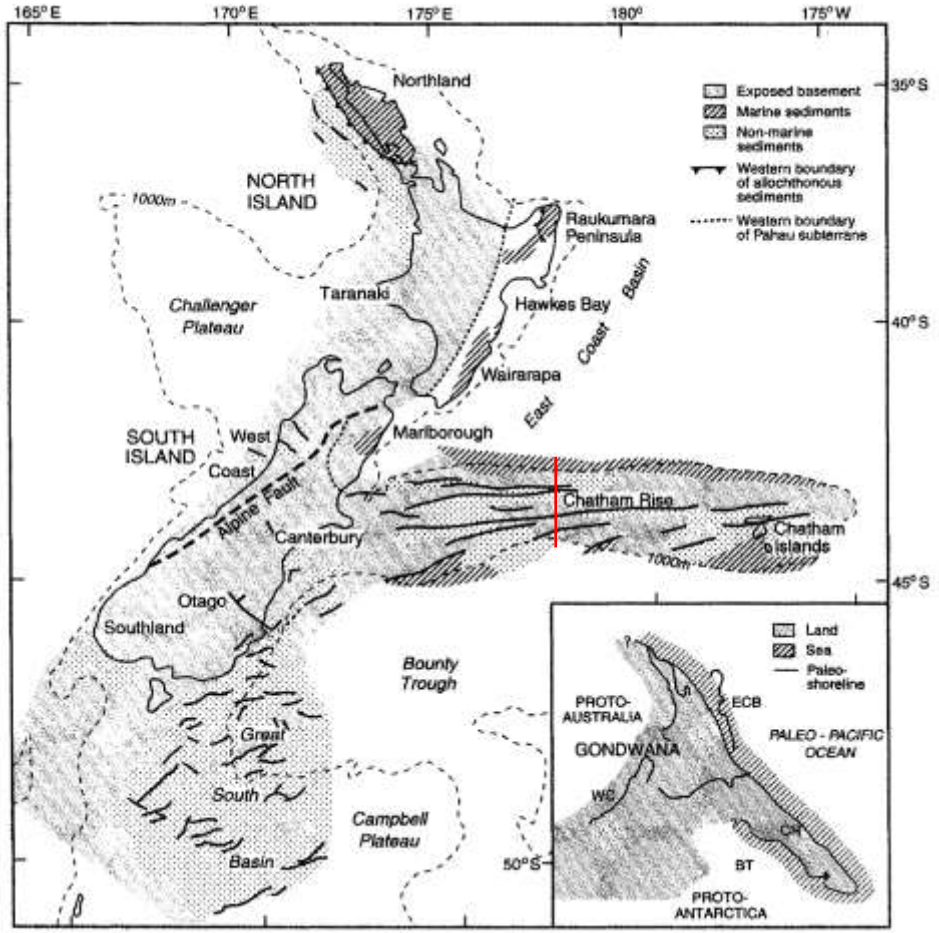
Phosphate known from samples on the Chatham Rise since 1952

Chatham Rock Phosphate holds an exploration license over part of the Rise, has applied for a mining license

Kenex is involved in application processing, database management, surveying and prospective/geological modelling

Kenex
Creating opportunities in the spatial world

Tectonic Setting

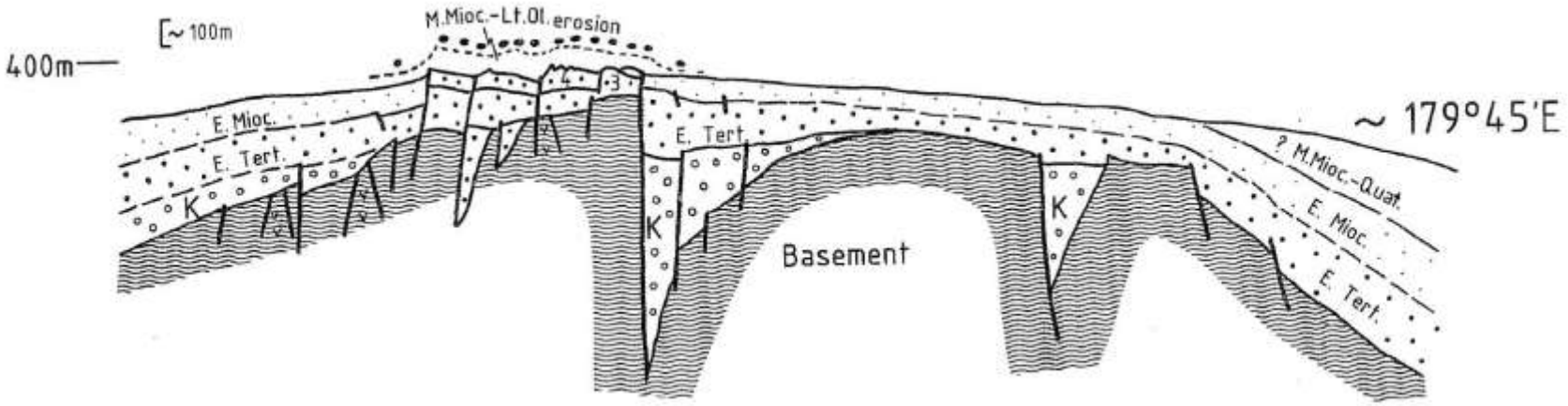


Laird & Bradshaw 2004

- Coherent structural high extending 1100 km east from the South Island.
- Formed through Late Cretaceous rifting from Gondwana, as a volcanic arc.
- The Chatham Peninsula persisted through the Paleocene, followed by limestone deposition in the central and east.

Kenex
Creating opportunities in the spatial world

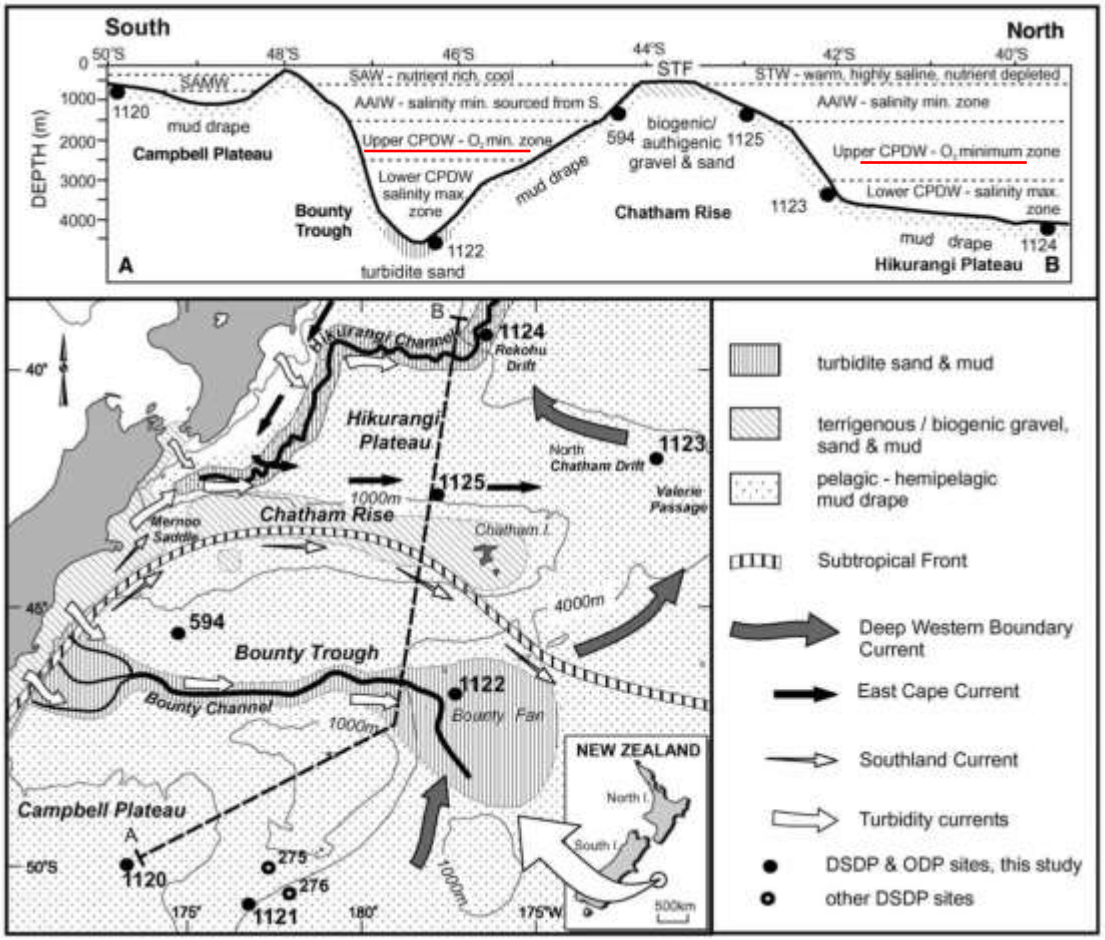
Geology



- Cretaceous faulted basement and fault basin fill, followed by hiatus
- Late Eocene cherty marl/limestone– Early Oligocene soft to firm nannofossil chalk, followed by hiatus
- Mid-Miocene limestone and hardground, phosphatised to nodular gravel in Late Miocene as lag deposit on firm to hard Oligocene top surface, overlain by soft Neogene terrigenic/glauconitic mud.
- Late Neogene phosphatisation, glauconitisation and glacial influence in the Plio-Pleistocene.

Either nodules are the same age as underlying chalk, phosphatisation younger and possibly multistage (von Rad et al 1984)
Or: Early-mid Miocene chalk phosphatised in Late Miocene (12 – 7 Ma, Cullen 1987).

Oceanographic Setting



Modern Subtropical Front on southern flank of Chatham Rise.

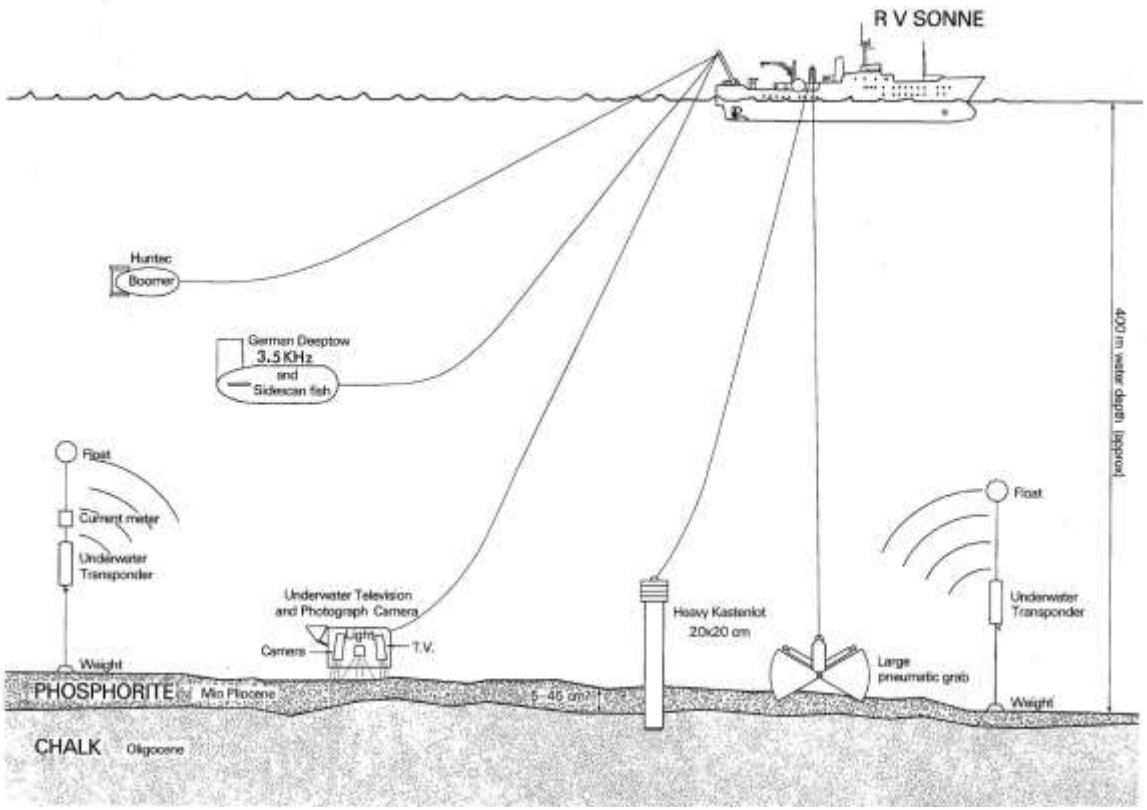
O2 minimum zone associated with Upper Circumpolar Deep Water

Important feature in S. Pacific paleoceanography.

Deep coring mostly on flanks and in adjacent basins (crest = condensed section).

Hayward et al 2004

Sampling efforts

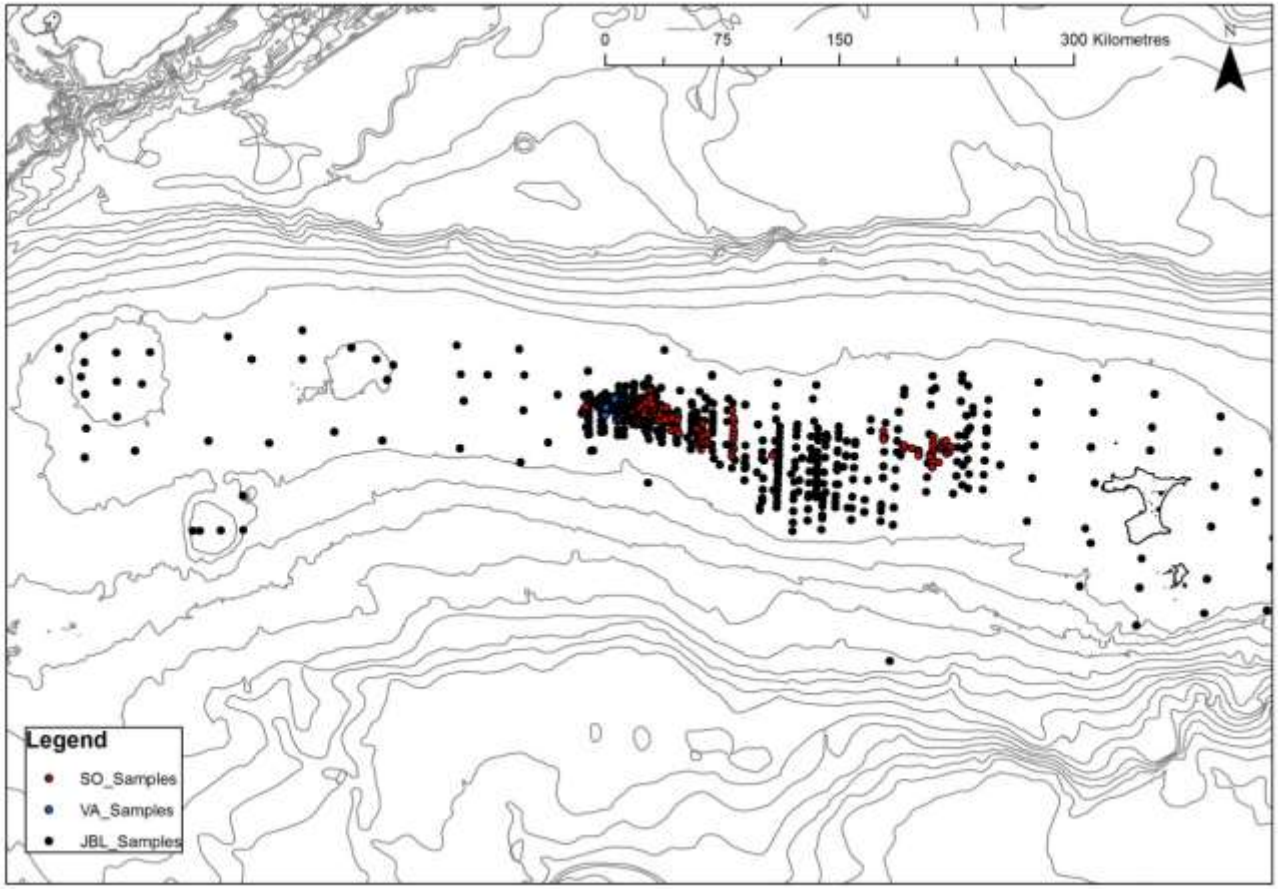


Surveys in the 60s (Global Marine/JBL), 1978 (*Valdivia*) and 1981 (*Sonne*)

Methods include high-resolution seismics and shallow-penetration sampling.

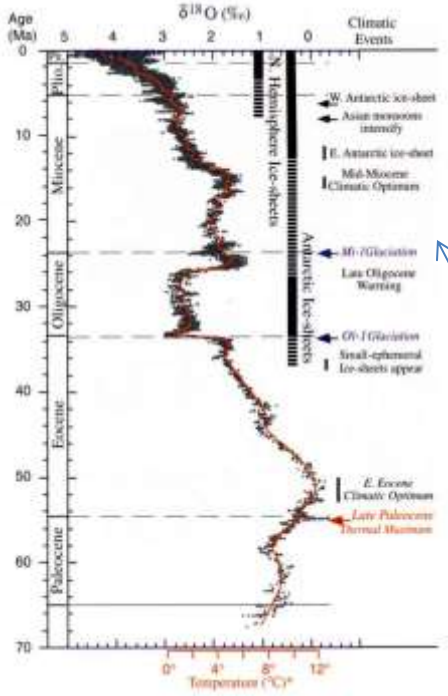
Kenex
Creating opportunities in the spatial world

Sample distribution

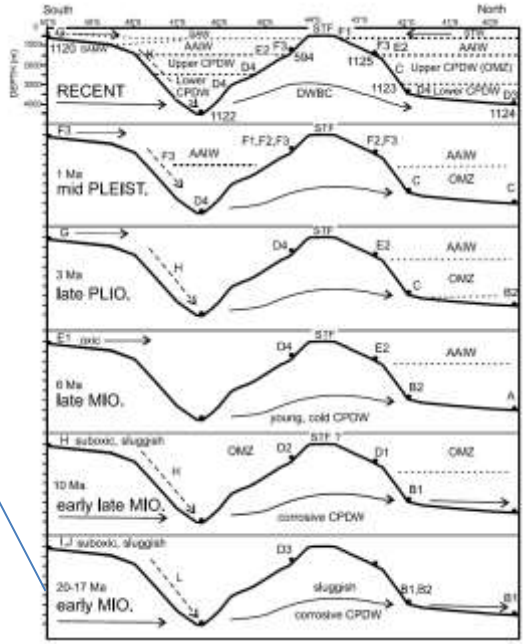


Kenex
Creating opportunities in the spatial world

Paleoclimatology



Zachos 2001



Hayward et al 2004

Deep OMZ

Shallow OMZ

Shallow OMZ needed for phosphatisation on crest?

Phosphatisation during older Austral cooling events as well? (m. Eocene, Eo/Oligo, Oligo/Mio?)

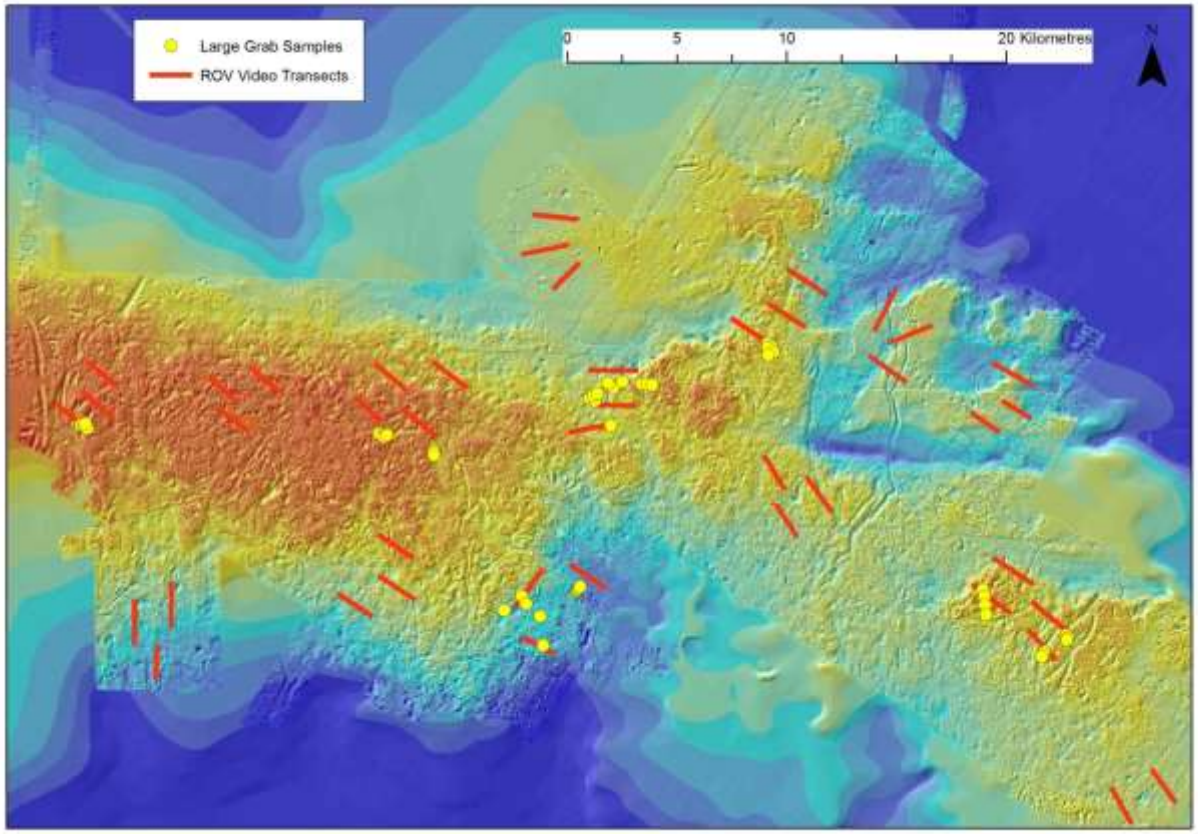
Kenex
Creating opportunities in the spatial world

CRP 2011/2012 Surveys

- 4 surveys from Dec 2011 – April 2012
- > 200 samples using grabs, box corers and vibro coring.
- > 1100 km^2 of multibeam bathymetry
- > 100 km of ROV transects

Kenex
Creating opportunities in the spatial world

CRP 2011/2012 Surveys



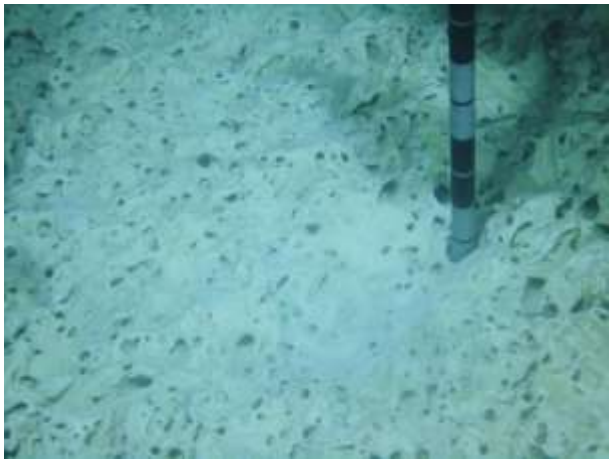
Irregular seabed, with (glacial) scours and pits

50 large grab samples (500 – 2000 kg / sample)

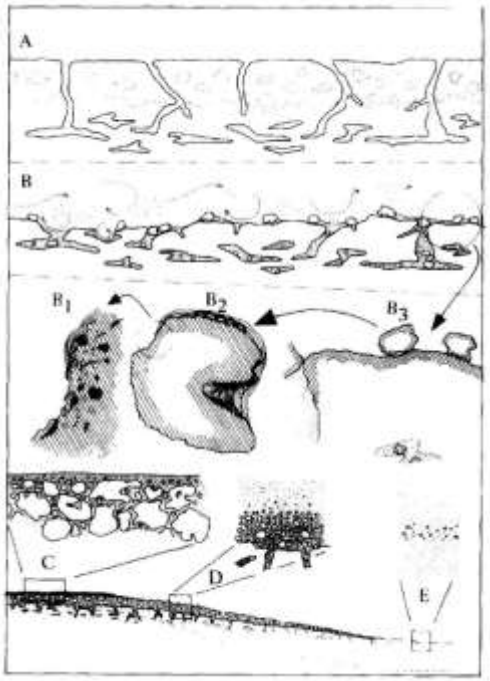
43 ROV transects for environmental studies

Kenex
Creating opportunities in the spatial world

Seafloor Characteristics



- Soupy glauconitic sandy mud over lag layer of phophatised hardground nodules
- Substrate is a stiff, intensely bioturbated pelagic chalk.



Pedley and Bennett, 1985

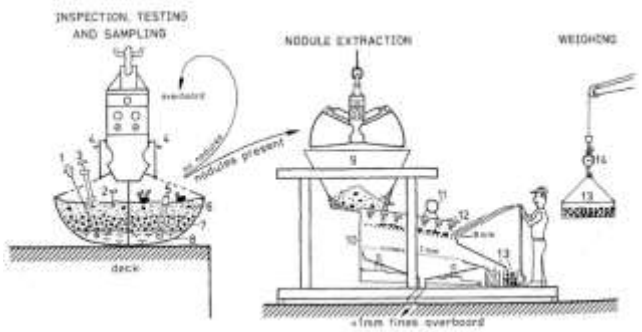
Kenex
Creating opportunities in the spatial world

Sampling method

The larger the grain size, the smaller the sample…

Kenex
Creating opportunities in the spatial world

Large samples, large efforts



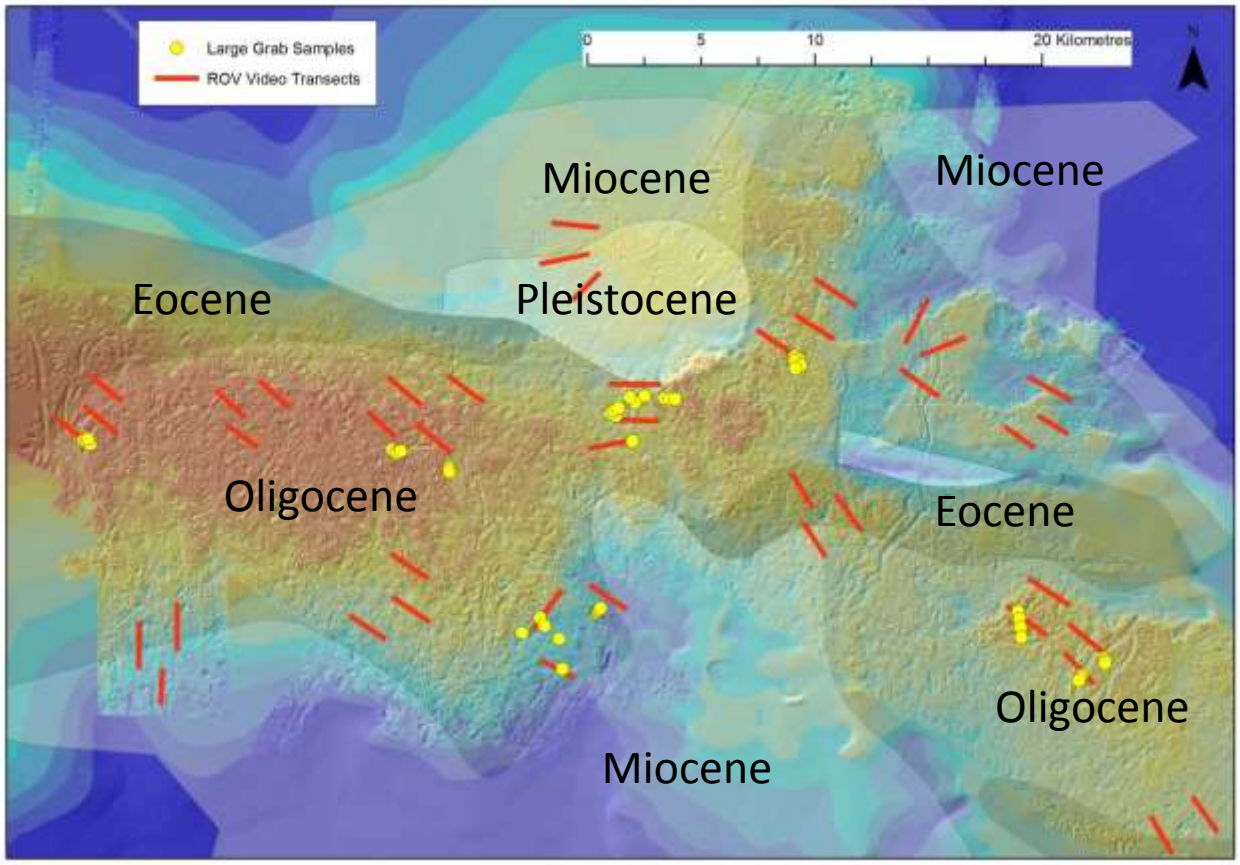
Onboard sample processing,
R/V *Sonne* 1981
Fines were thrown back.

Von Rad & Rösch 1984

Onshore sample processing, 2012
Fines were kept, if washed with freshwater

Kenex
Creating opportunities in the spatial world

Multiple Events? Nodule Shape



Seismic facies (Falconer *et al.* 1984)

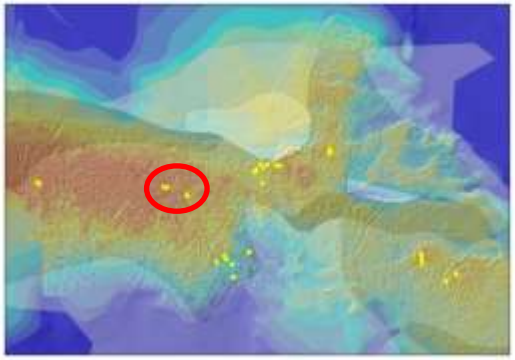
- Older hardgrounds may have undergone more intensive alteration leading to smoother texture and rounder shape
- Samples mainly from Oligocene seismic facies…

Kenex
Creating opportunities in the spatial world

Nodule Shape - Middle of Crest

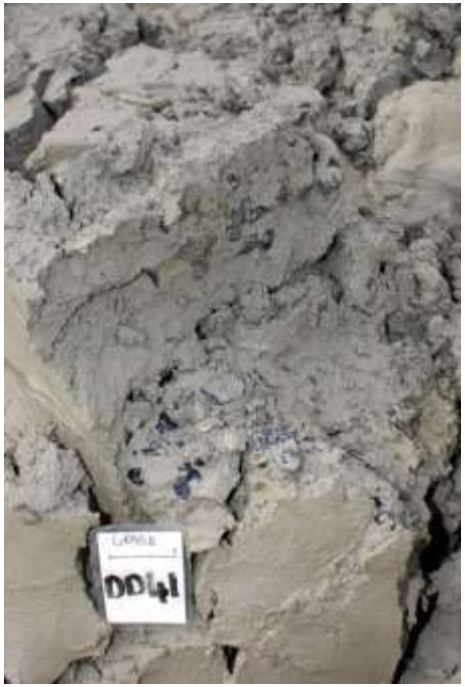
Round/smooth = most intense alteration
Irregular/rough = less alteration

Rounded, smooth nodules
Most ‘mature’ deposit?



Kenex
Creating opportunities in the spatial world

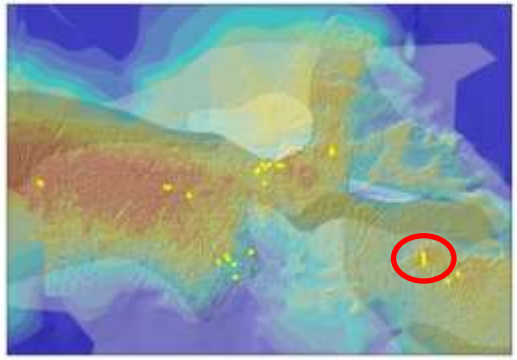
Nodule Shape - Eastern Area



Pitted nodules, obvious bores/burrows

Partially phosphatised and less altered hardground

Less mature deposit?

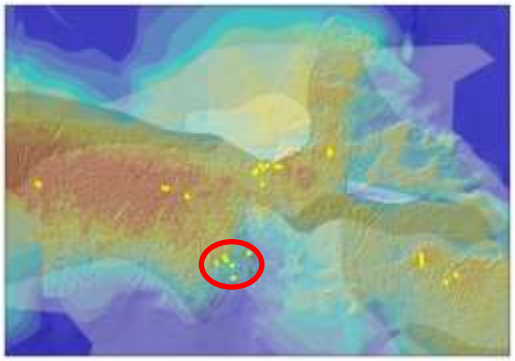


Kenex
Creating opportunities in the spatial world

Nodule Shape - Southern area

Irregular nodules, obvious bores/burrows.

Less mature deposit?

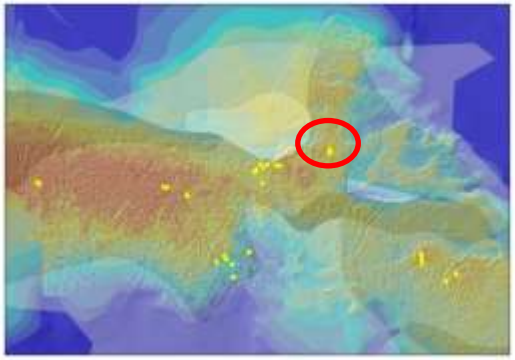


Kenex
Creating opportunities in the spatial world

Nodule Shape - Northern Area

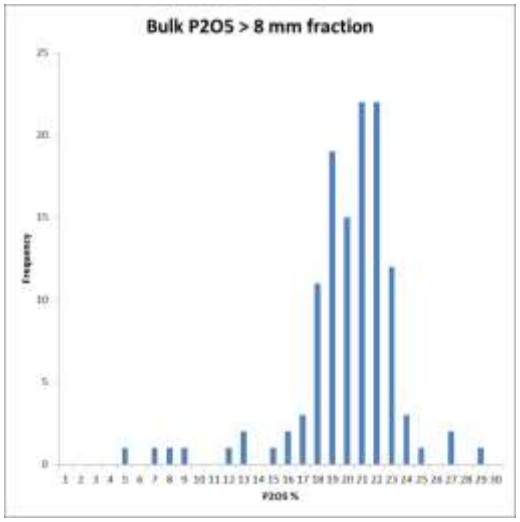
Irregular nodules, pitting, bores, and burrows.

Less mature deposit?



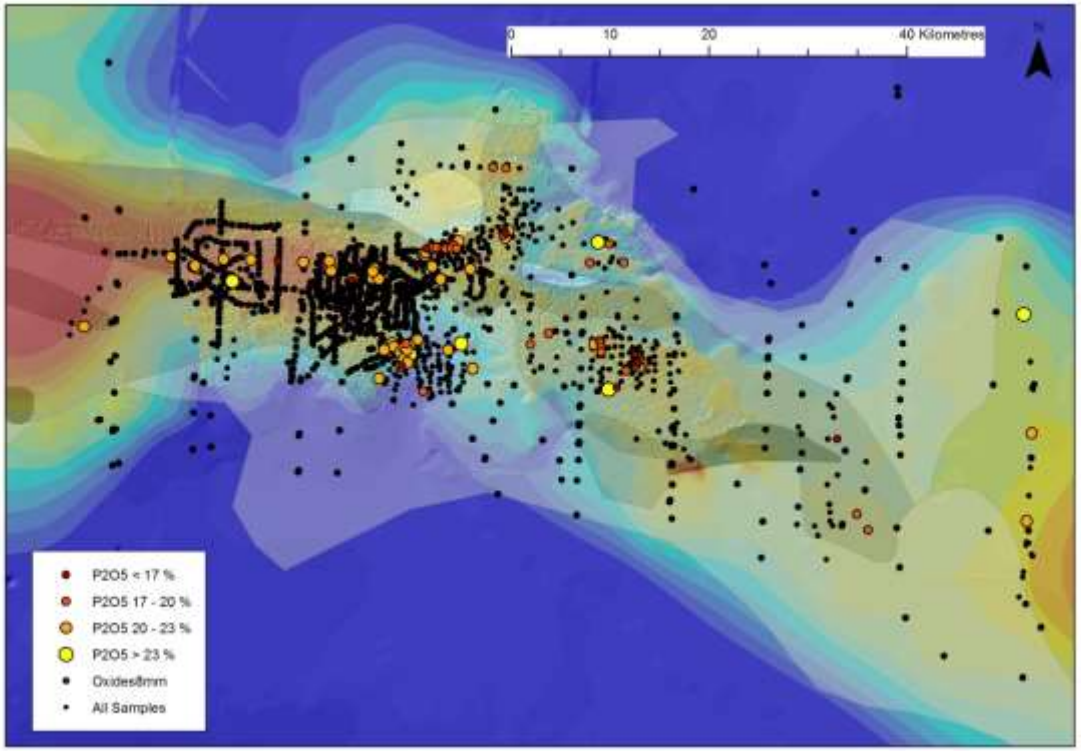
Kenex
Creating opportunities in the spatial world

Intensity of Phosphatisation



116 samples with XRF geochemistry (out of > 1400)

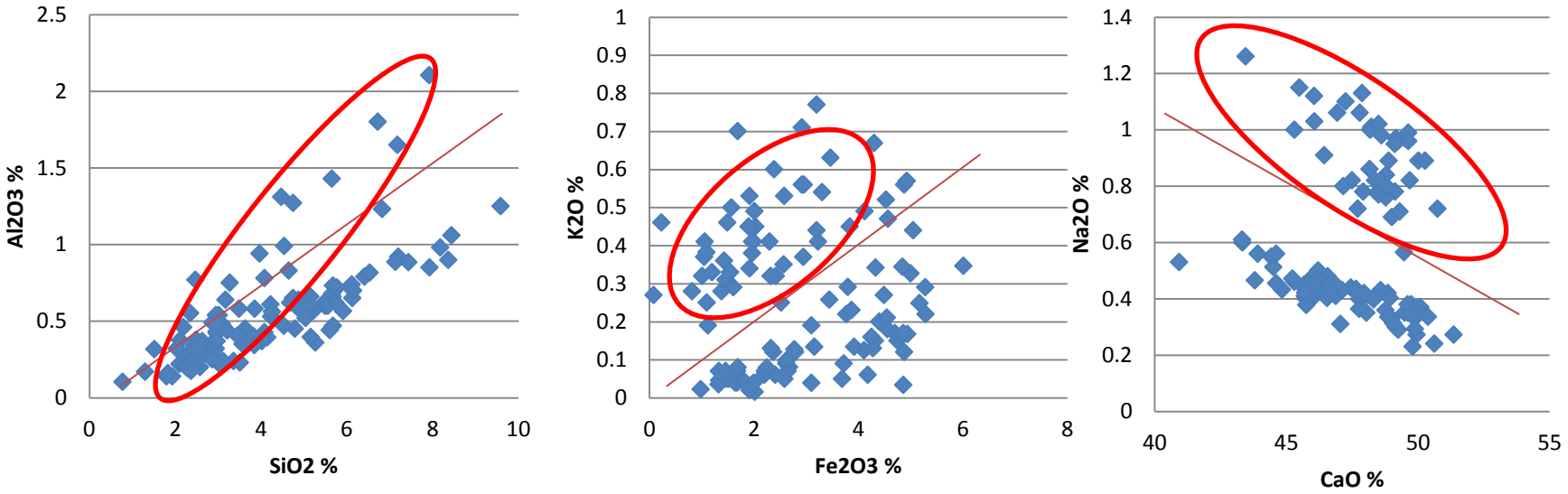
Tendency for low (and highest?) P points to fall on the periphery



Bulk (XRF) geochemistry, > 8 mm

Kenex
Creating opportunities in the spatial world

Geochemical Populations



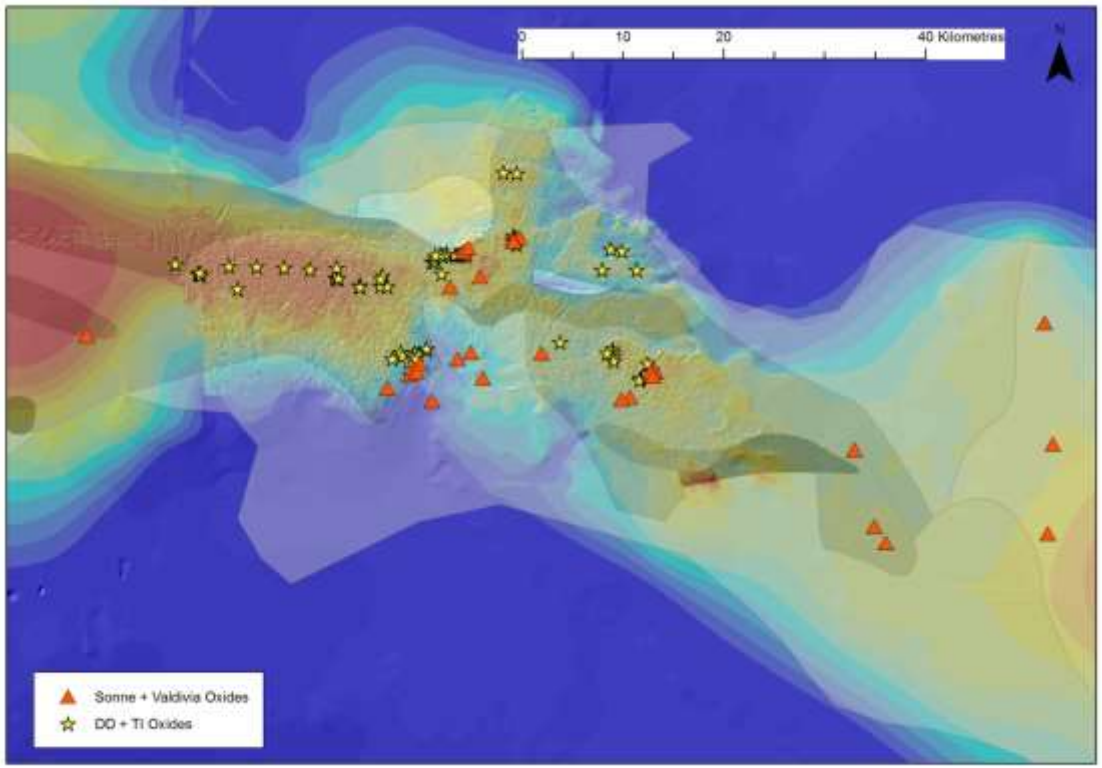
Bulk (XRF) geochemistry, > 8 mm fraction

Signs of 2 populations of phosphate nodule geochemistry
High Al + K = glauconite, but…

High Al + K + Na samples are almost exclusively Sonne/Valdivia samples

Kenex
Creating opportunities in the spatial world

Geochem. Population Distribution

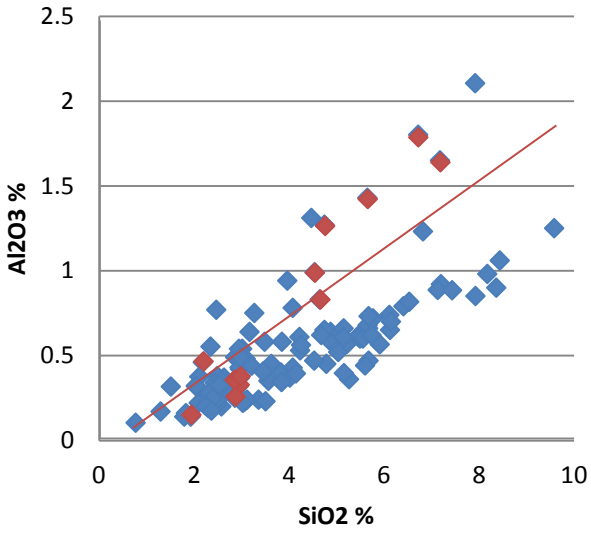


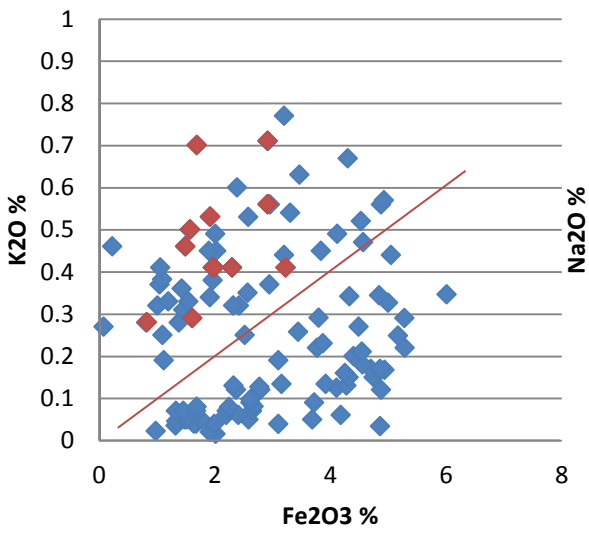
DD and Ti samples are from the western (northern) region, and generally in Oligocene sediment facies.

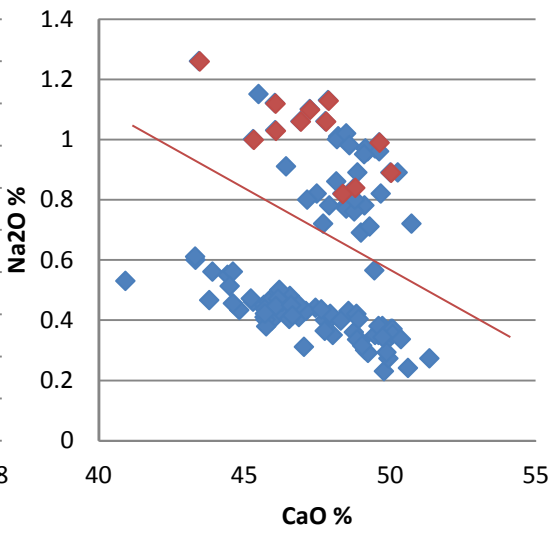
So and Va samples are from the south and east, and often in younger (Miocene) sediment facies.

Kenex
Creating opportunities in the spatial world

Oligocene vs. Miocene Nodules





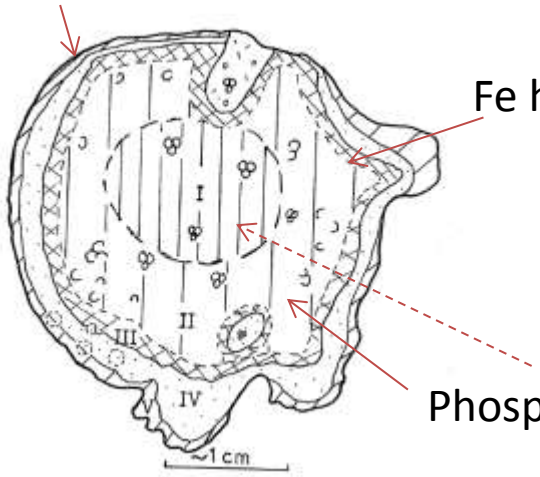


Are the Miocene samples (red points) less ‘mature’?

Kenex
Creating opportunities in the spatial world

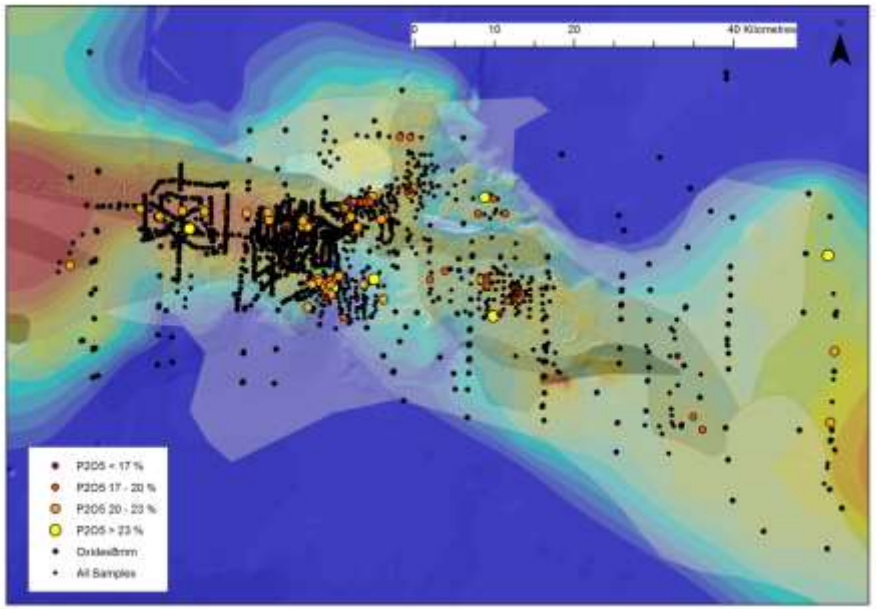
Will the nodules tell the story?

Glauconite



Fe hydroxide

Phosphate



Phosphatisation progressed inwards from the outside.

Can detailed analysis of nodules show multiple phases of alteration? (backscatter, scanning XRF)

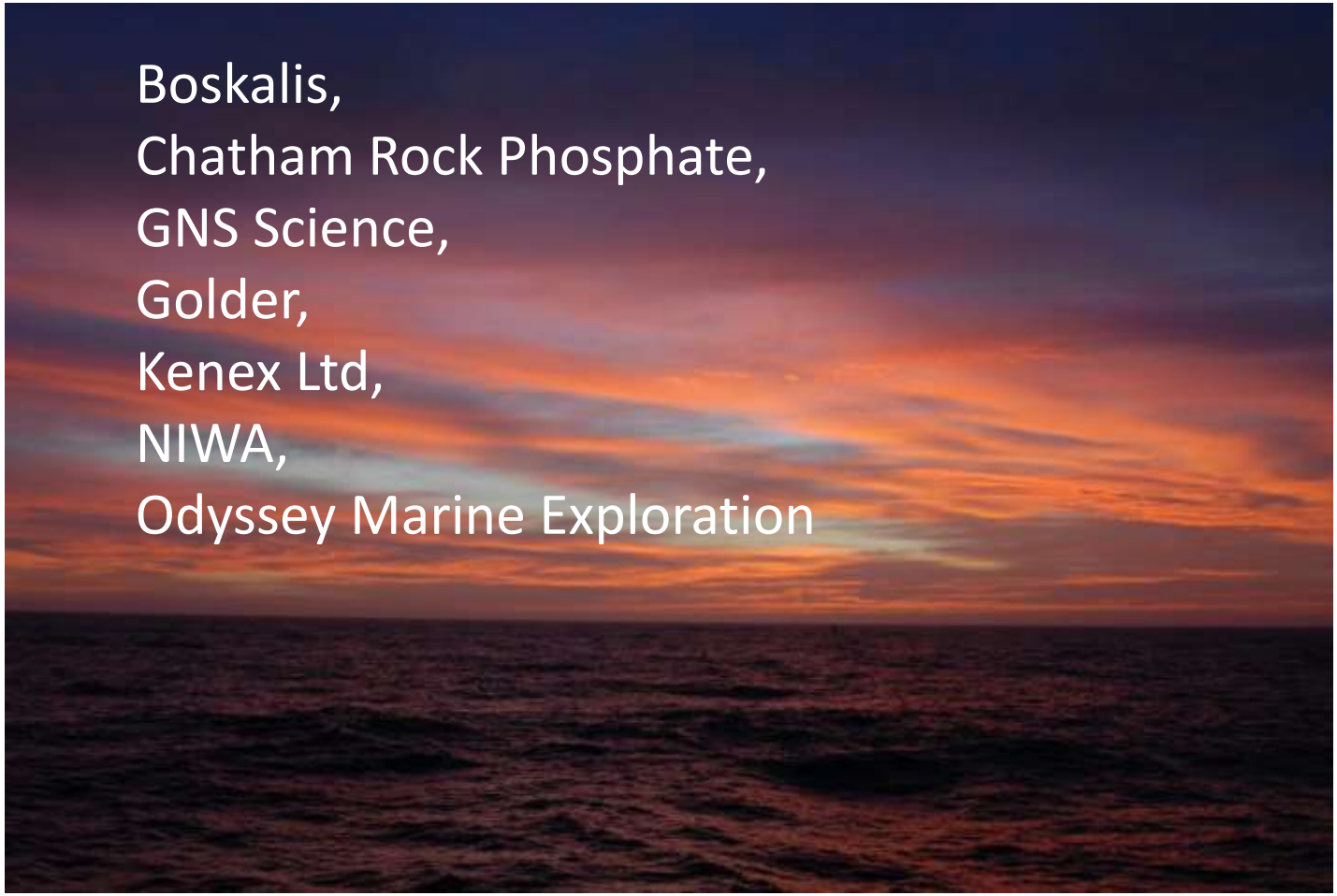
Samples from a wider area wanted!

Kenex
Creating opportunities in the spatial world

Conclusions

- Chatham Rise is covered by cool-water pelagic carbonate, hardground rubble and unconsolidated sandy mud. Sediment ages and hiati tie in with onshore geology (multiple Marshall Paraconf. equivalents?)
- Hardground formation associated with influx of cool bottom water from Antarctic/Southern Ocean events. Phosphatisation associated with OMZ establishment and fluctuation (only shallow OMZ?)
- Nodule shape and texture suggests most ‘mature’ nodules on the crest compared to margins. Most evenly phosphatised samples are found on the crest compared to the margins (most erosion on crest?)
- Most geochemically immature nodules are associated with marginal and younger sediment facies (lab factor versus locality issues)
- Individual nodule analysis can reveal possible multistage phosphatisation

Thanks to Collaborators at…



Kenex
Creating opportunities in the spatial world

PO Box 41136, Wellington, New Zealand
W: www.kenex.co.nz
E: info@kenex.co.nz

Kenex
Creating opportunities in the spatial world