Effects of Oil and Gas Exploration and Development at Selected Continental Slope Sites in the Gulf of Mexico: Final Conclusions

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Deepwater Operations Are Significantly Different from Conventional Operations on the Continental Shelf

- Farther from shore
- Different environmental conditions encountered
- Technologically more sophisticated
- Much higher production rates possibly involved

Purpose

Impacts of Drilling Activities on the Benthic Environment Around Deepwater Wellsites

Findings will assist the MMS in

- **Conducting environmental analyses**
- **Developing mitigative measures and regulations specifically tailored to deepwater operations**

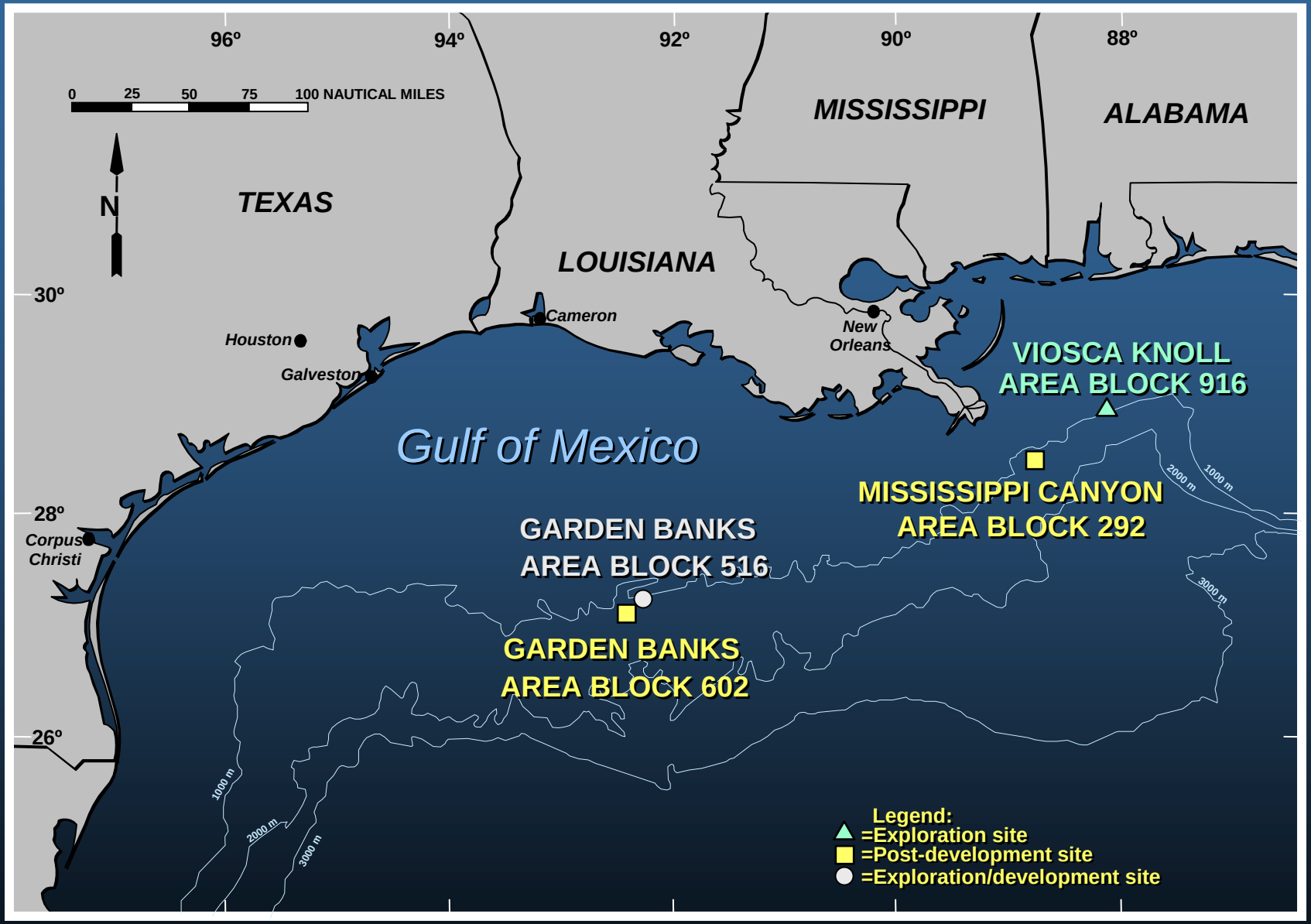
Objective

Assess the physical, chemical, and biological impacts of oil and gas development at selected exploration and development wellsites on the Gulf of Mexico continental slope:

- Drilling mud and cuttings accumulations
- Physical modification/disturbance of the seabed due to anchors and their mooring systems
- Debris accumulations
- Physical/chemical modification of sediments
- Effects on benthic organisms

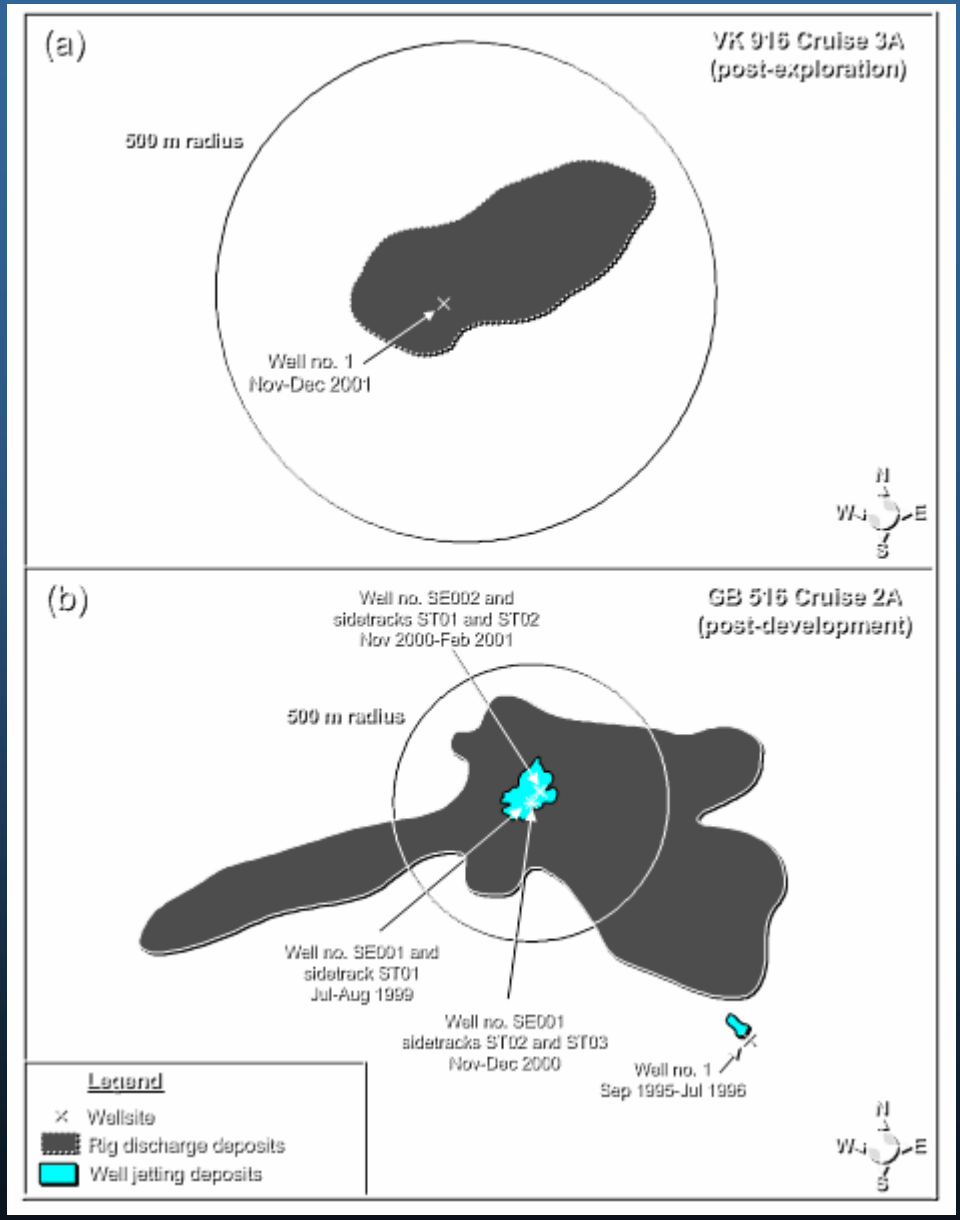
Overview

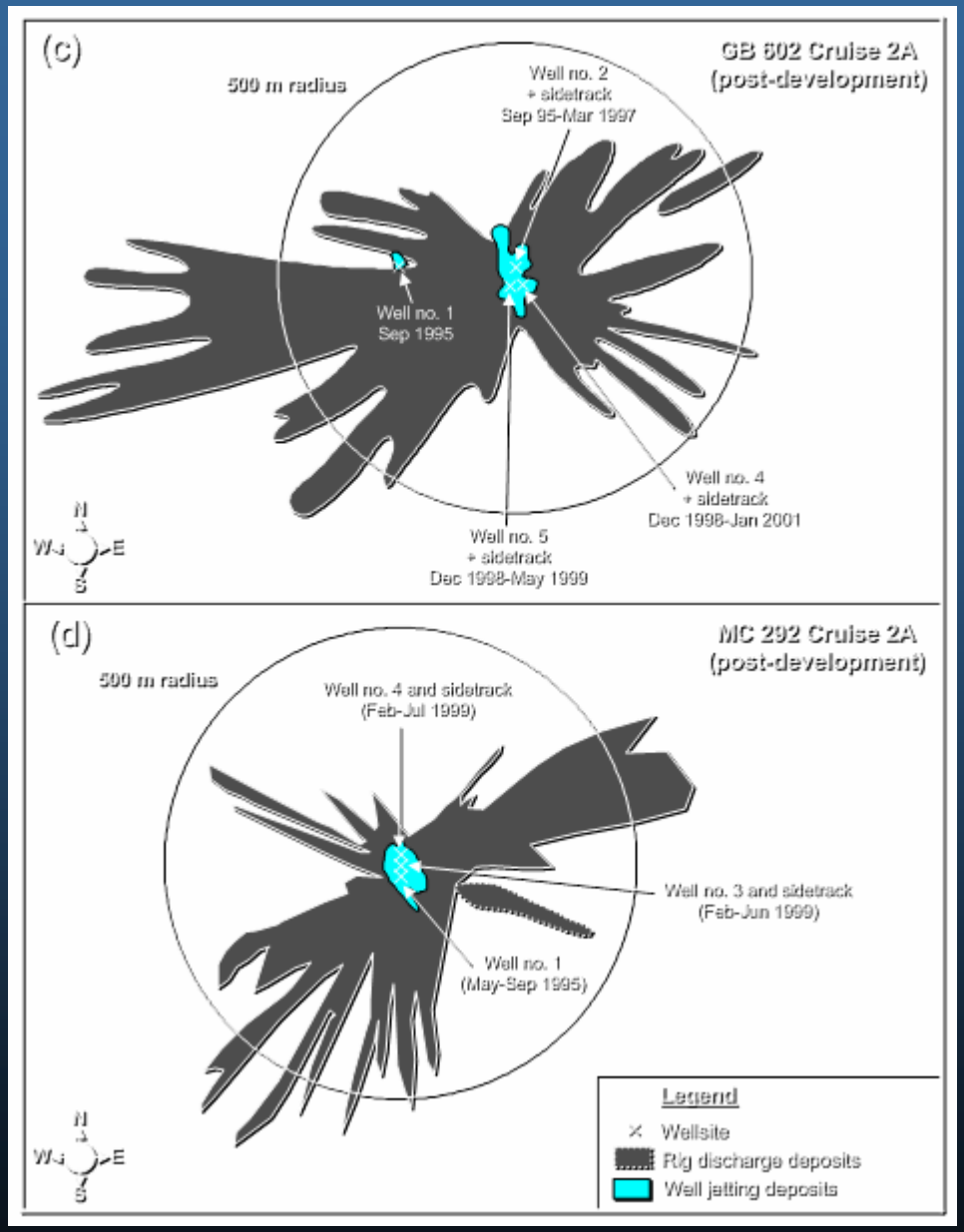
- Four study sites
  - Water depths about 1000–1150 m
  - Reference areas for each study site –10 to 25 km away from wellsite
- Six cruises
  - Three geophysical mapping included bathymetry, side-scan sonar, subbottom profiling
  - Three chemical/biological surveys included box coring, sediment profile imaging, seafloor photographs, baited traps (for tissue samples)

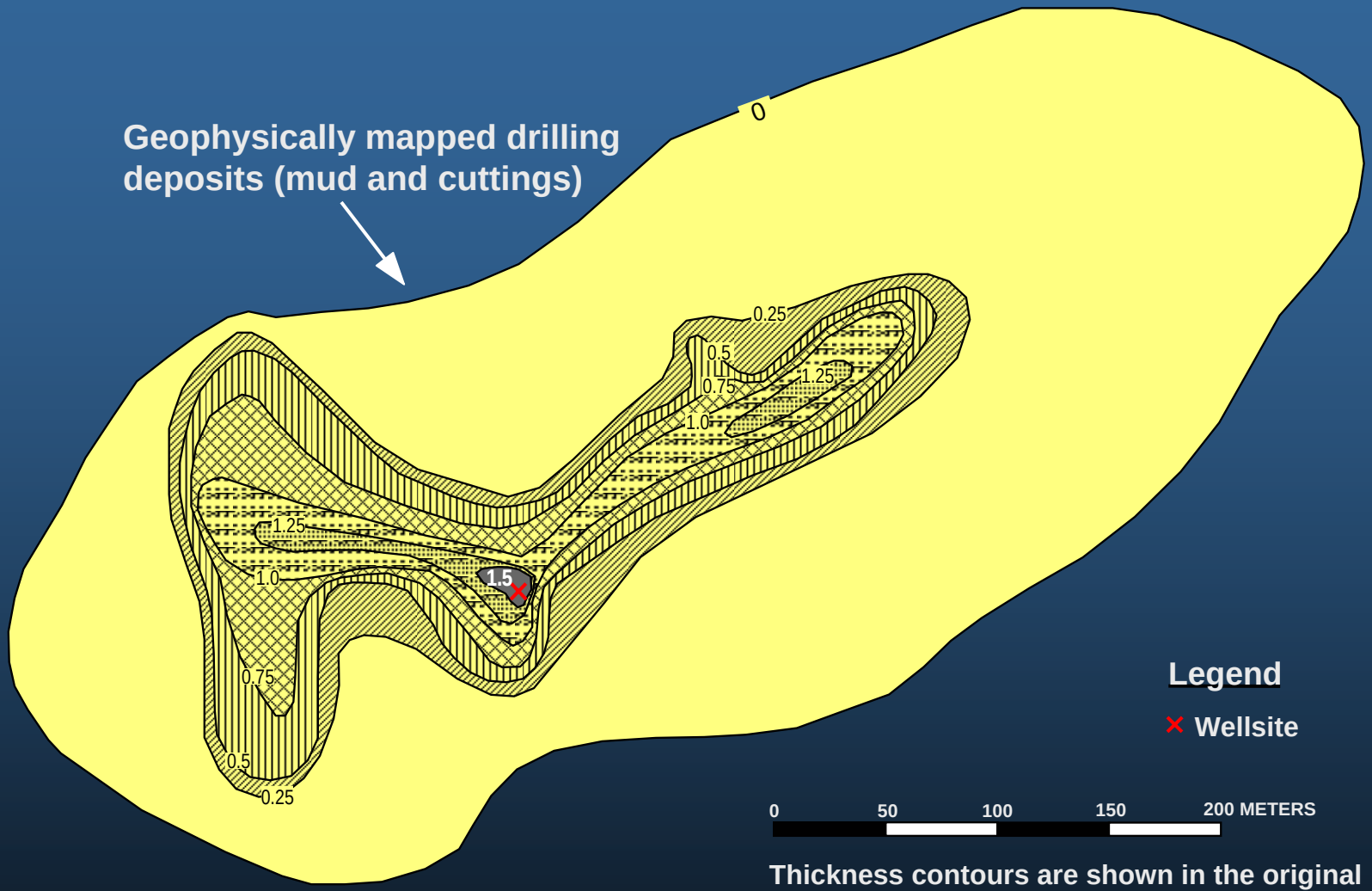

96º
94º
92º
90º
88º
0 25 50 75 100 NAUTICAL MILES
N
TEXAS
LOUISIANA
MISSISSIPPI
ALABAMA
30º
28º
26º
Houston
Galveston
Cameron
New Orleans
Corpus Christi
Gulf of Mexico
VIOSCA KNOLL AREA BLOCK 916
MISSISSIPPI CANYON AREA BLOCK 292
GARDEN BANKS AREA BLOCK 516
GARDEN BANKS AREA BLOCK 602
1000 m
2000 m
3000 m
Legend:
=Exploration site
=Post-development site
=Exploration/development site

Geophysical Measurements

- SBM cuttings and muds deposited within the near-field radius
- Areas mapped as cuttings typically extended several hundred meters from wellsites to about 1 km
- The cuttings deposits were estimated to be up to 45 cm thick at VK 916


(a)
VK 915 Cruise 3A
(post-exploration)
500 m radius
Well no. 1
Nov-Dec 2001
N
W
E
S
(b)
GB 515 Cruise 2A
(post-development)
Well no. SE002 and
sidetracks ST01 and ST02
Nov 2000-Feb 2001
500 m radius
Well no. SE001 and
sidetrack ST01
Jul-Aug 1999
Well no. SE001
sidetracks ST02 and ST03
Nov-Dec 2000
Well no. 1
Sep 1995-Jul 1996
Legend
Wellsite
Rig discharge deposits
Well jetting deposits
N
W
E
S

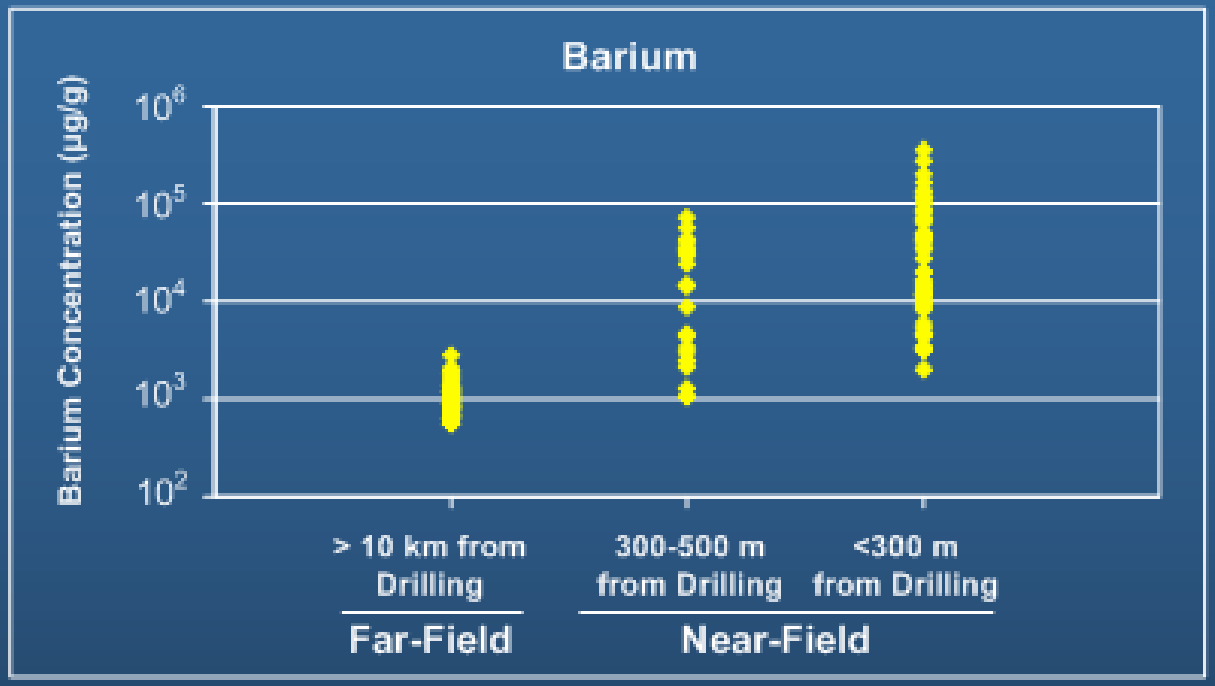

(c)
GB 602 Cruise 2A
(post-development)
500 m radius
Well no. 2
+ sidetrack
Sep 95-Mar 1997
Well no. 1
Sep 1995
Well no. 4
+ sidetrack
Dec 1998-Jan 2001
Well no. 5
+ sidetrack
Dec 1998-May 1999
N
W
E
S
(d)
MC 292 Cruise 2A
(post-development)
500 m radius
Well no. 4 and sidetrack
(Feb-Jul 1999)
Well no. 3 and sidetrack
(Feb-Jun 1999)
Well no. 1
(May-Sep 1995)
N
W
E
S
Legend
Wellsite
Rig discharge deposits
Well jetting deposits

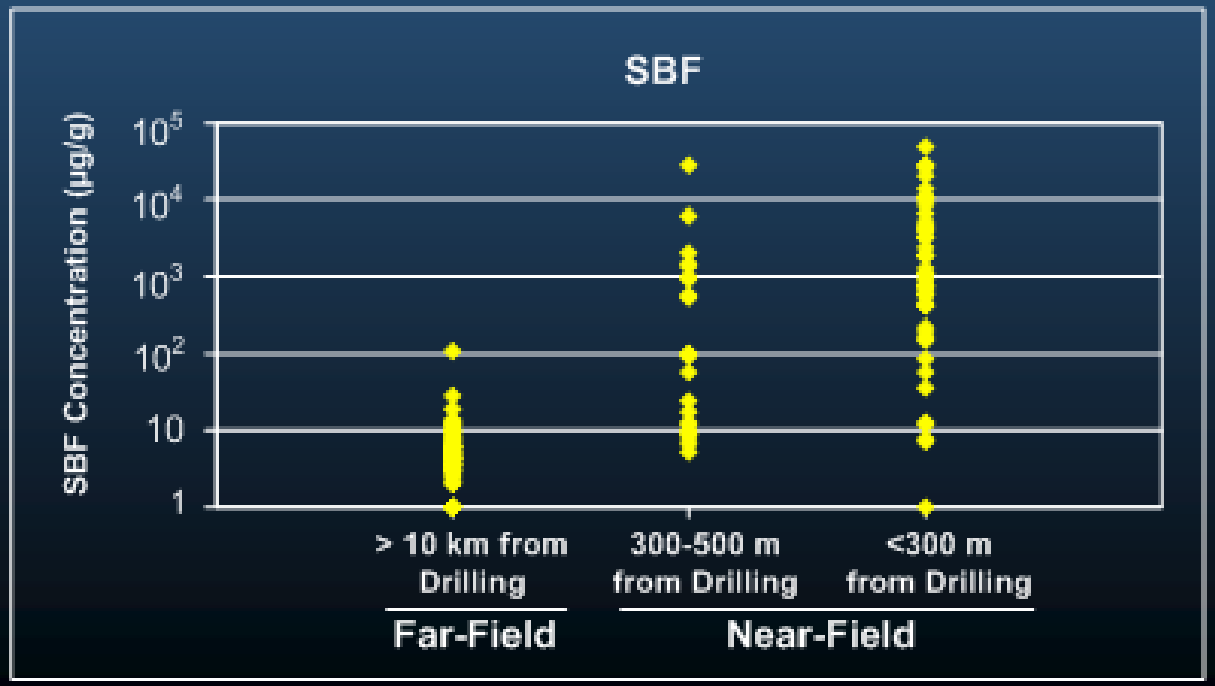


Thickness contours are shown in the original units (ft). 1 ft = 30 cm

Chemical Measurements Barium and SBF

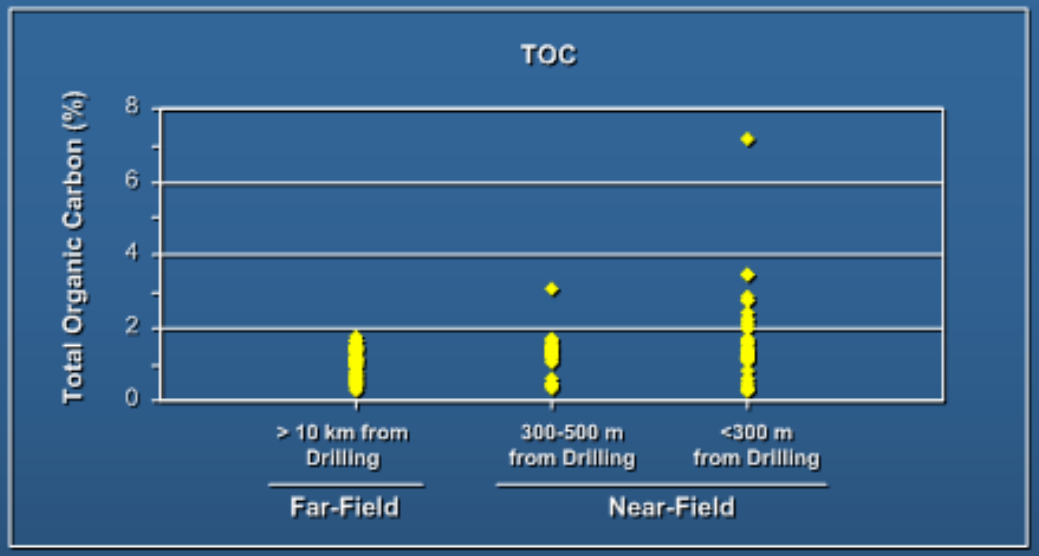
- Concentrations elevated by several orders of magnitude within near-field sites
- Mean sediment concentrations positively correlated with estimated discharge volumes of SBM cuttings

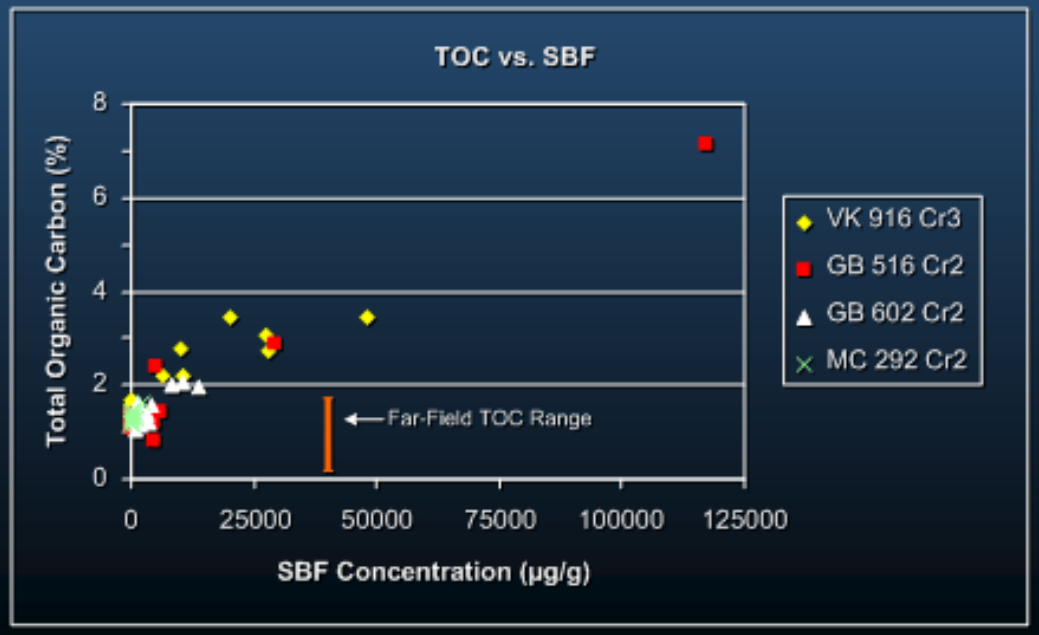

Barium
Barium Concentration (µg/g)
10^6
10^5
10^4
10^3
10^2
> 10 km from Drilling
300-500 m from Drilling
<300 m from Drilling
Far-Field
Near-Field

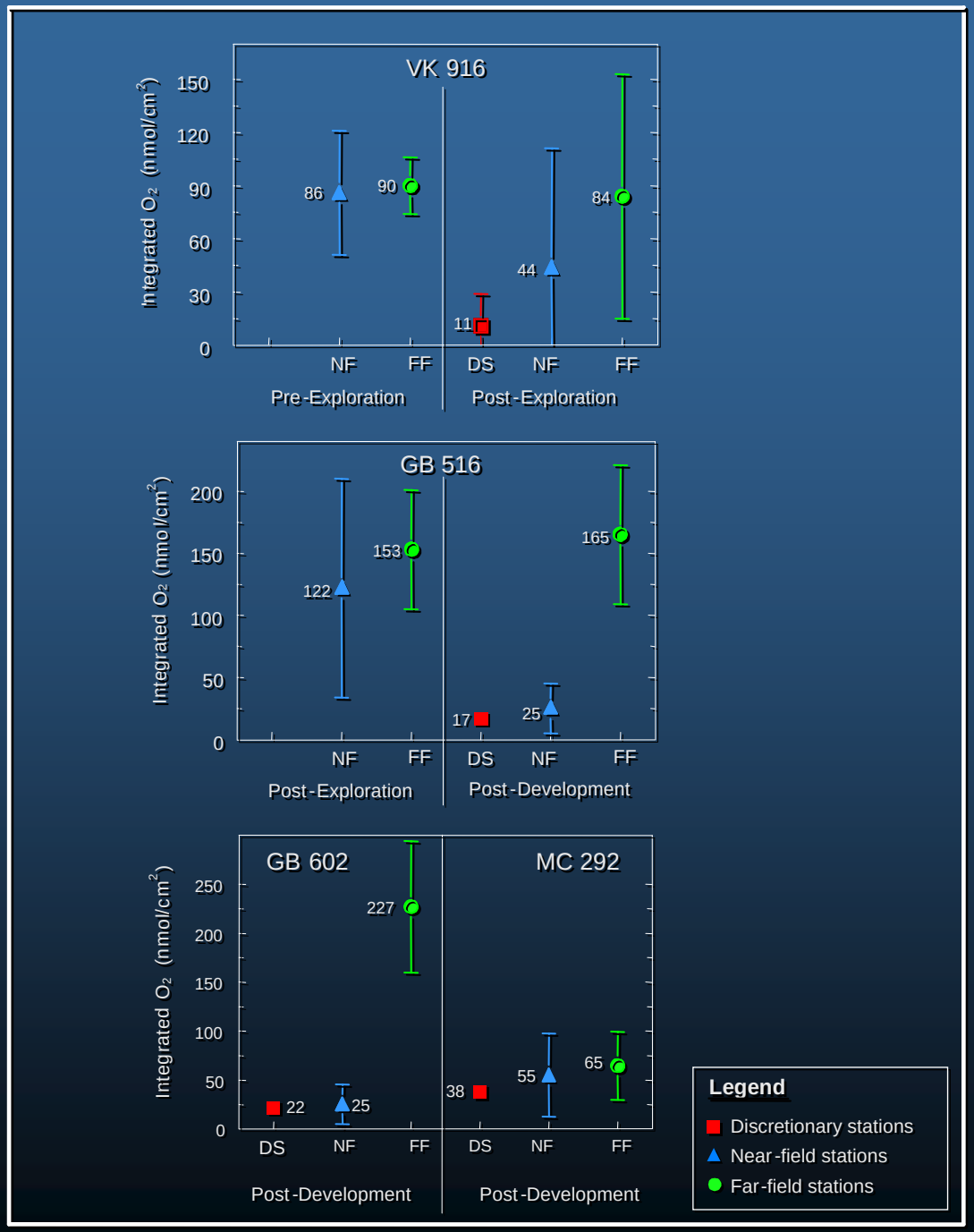

SBF
SBF Concentration (µg/g)
10^5
10^4
10^3
10^2
10
1
> 10 km from Drilling
300-500 m from Drilling
<300 m from Drilling
Far-Field
Near-Field

SBM Cuttings Deposition

- Areas of SBM cuttings deposition associated with
  - elevated TOC
  - low dissolved oxygen
  - negative Eh
  - shallow depth of the oxidized layer
- Larger volumes of SBM cuttings discharges and higher mean sediment SBF concentrations associated with greatest reduction in mean sediment oxygen levels


TOC
Total Organic Carbon (%)
8
6
4
2
0
> 10 km from Drilling
300-500 m from Drilling
<300 m from Drilling
Far-Field
Near-Field

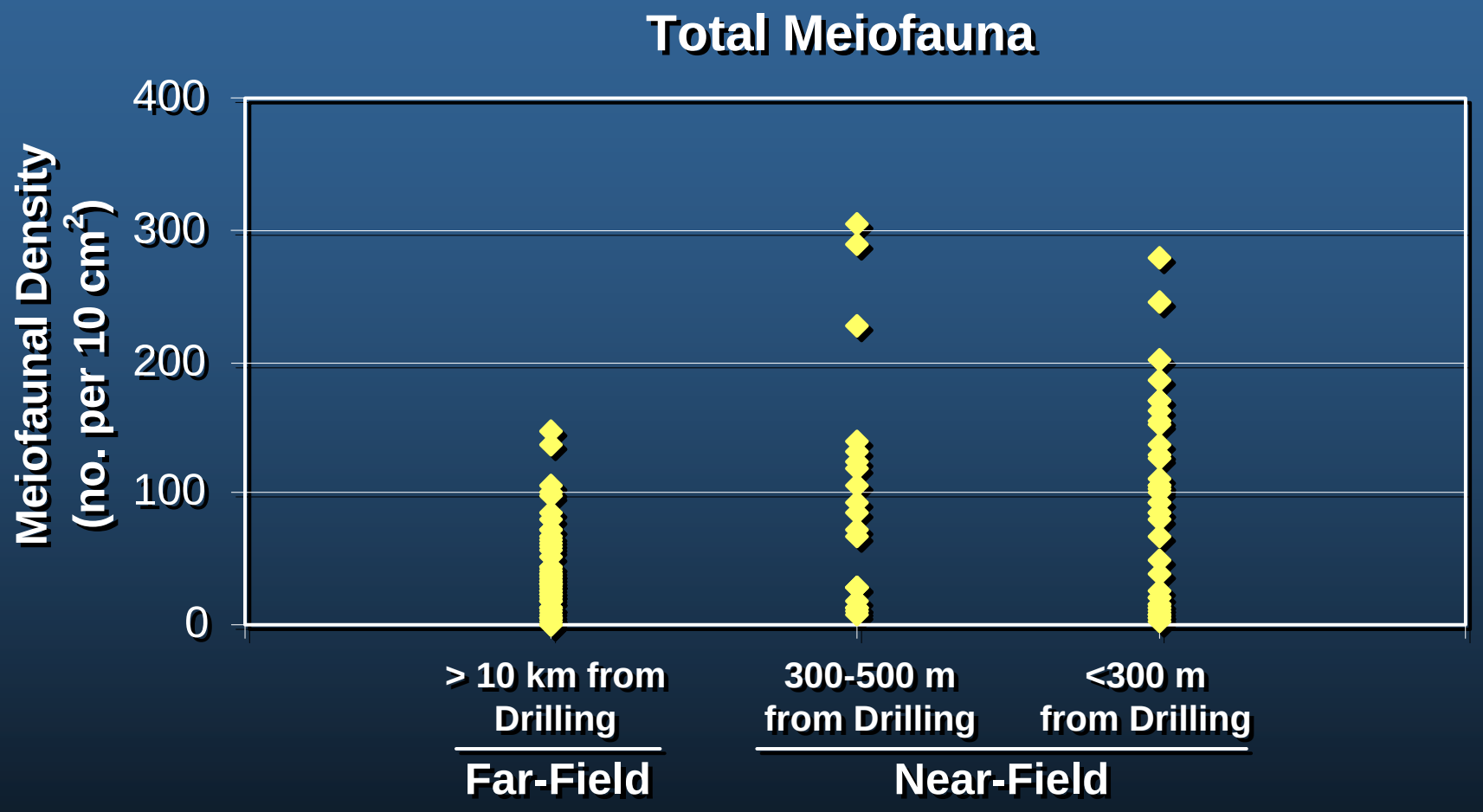

TOC vs. SBF
Total Organic Carbon (%)
8
6
4
2
0
0
25000
50000
75000
100000
125000
SBF Concentration (µg/g)
Far-Field TOC Range
VK 916 Cr3
GB 516 Cr2
GB 602 Cr2
MC 292 Cr2


VK 916
Integrated O2 (nmol/cm2)
150
120
90
60
30
0
86
90
11
44
84
NF
FF
DS
NF
FF
Pre-Exploration
Post-Exploration
GB 516
Integrated O2 (nmol/cm2)
200
150
100
50
0
122
153
17
25
165
NF
FF
DS
NF
FF
Post-Exploration
Post-Development
GB 602
MC 292
Integrated O2 (nmol/cm2)
250
200
150
100
50
0
227
22
25
38
55
65
DS
NF
FF
DS
NF
FF
Post-Development
Post-Development
Legend
Discretionary stations
Near-field stations
Far-field stations

Meiofauna

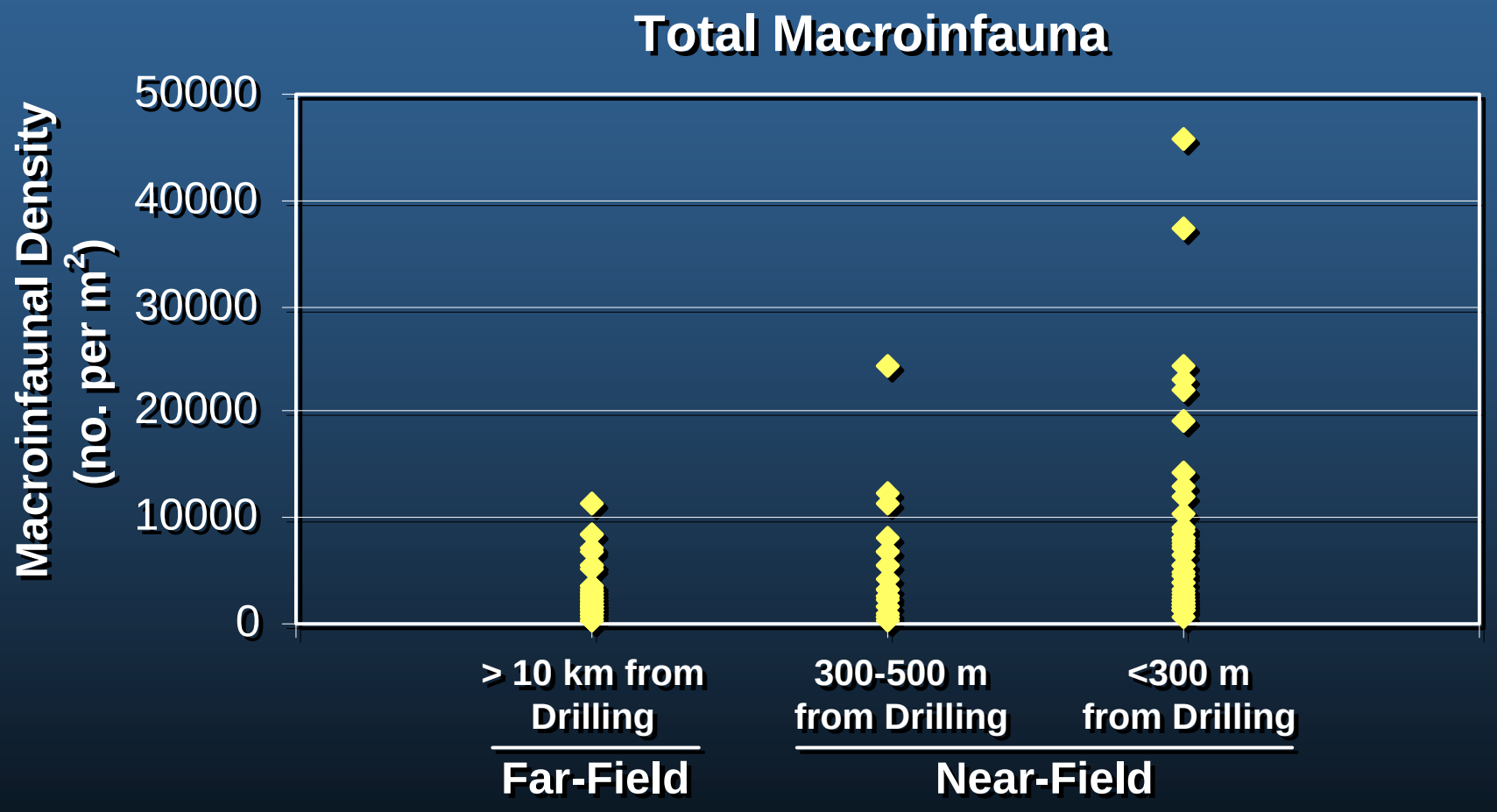
Densities generally greater near drilling

Not consistently correlated with drilling indicators (barium, SBF) or other sediment variables (TOC, grain size fractions)

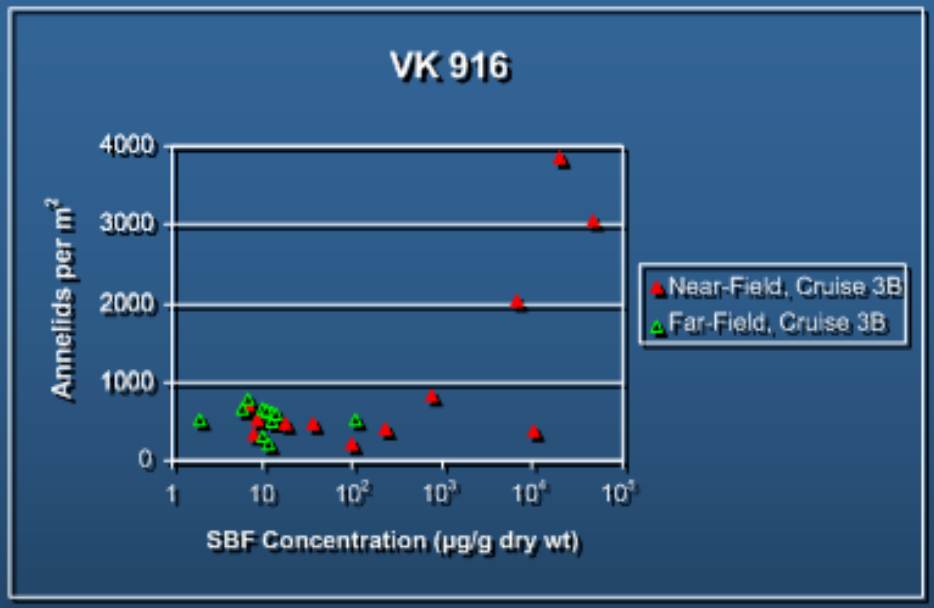

Total Meiofauna
Meiofaunal Density
(no. per 10 cm2)
400
300
200
100
0
> 10 km from Drilling
300-500 m from Drilling
<300 m from Drilling
Far-Field
Near-Field

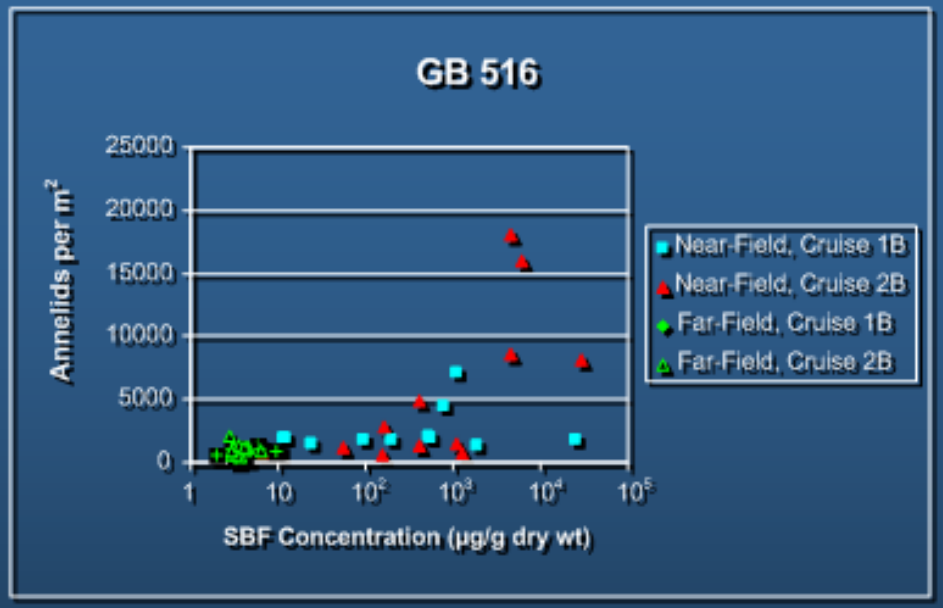
Macroinfauna

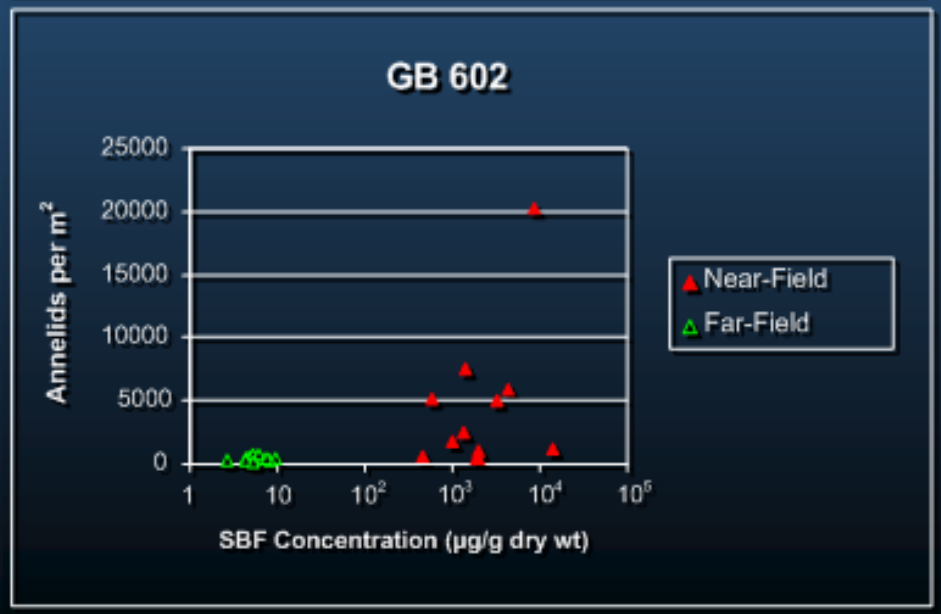
- Densities generally greater near drilling
- Annelids (predominantly polychaetes)
  - positively correlated with drilling indicators (barium, SBF)
- Gastropods
  - positively correlated with drilling indicators (barium, SBF)
- Amphipods
  - negatively correlated with drilling indicators (barium and SBF) in the near-field

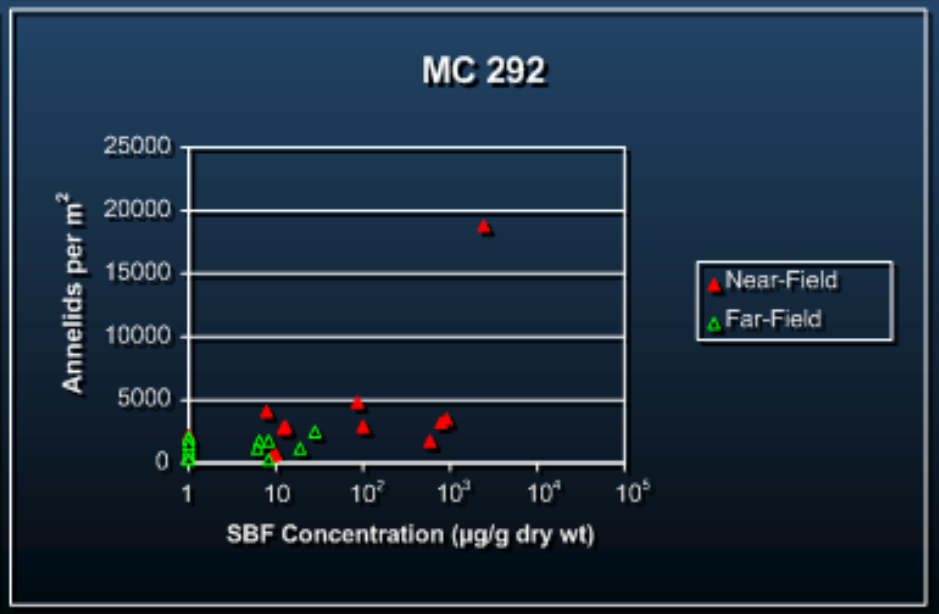

Total Macroinfauna
Macroinfaunal Density (no. per m2)
50000
40000
30000
20000
10000
0
> 10 km from Drilling
300-500 m from Drilling
<300 m from Drilling
Far-Field
Near-Field

Annelids

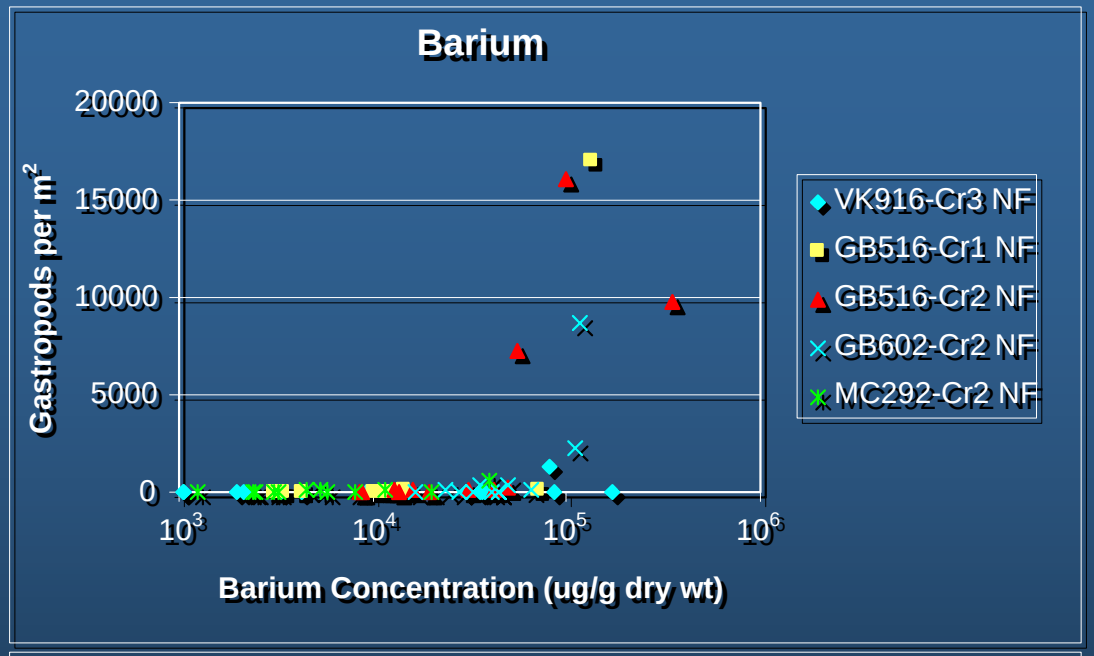

VK 916
Annelids per m²
4000
3000
2000
1000
0
1
10
10²
10³
10⁴
10⁵
SBF Concentration (µg/g dry wt)
Near-Field, Cruise 3B
Far-Field, Cruise 3B

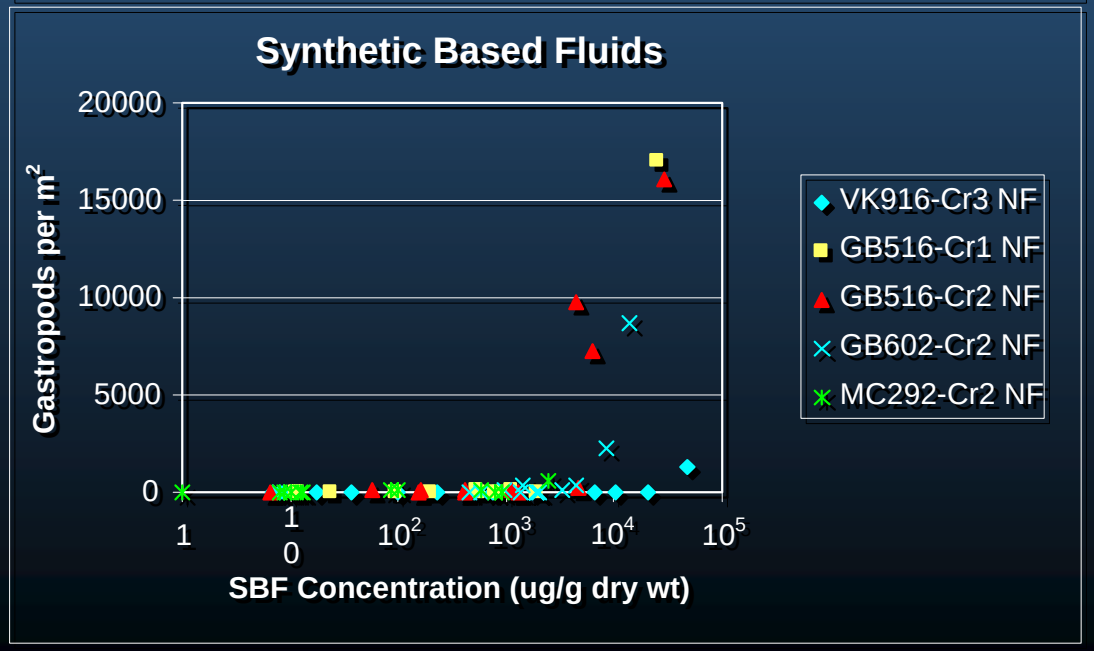

GB 516
Annelids per m²
25000
20000
15000
10000
5000
0
1
10
10²
10³
10⁴
10⁵
SBF Concentration (µg/g dry wt)
Near-Field, Cruise 1B
Near-Field, Cruise 2B
Far-Field, Cruise 1B
Far-Field, Cruise 2B


GB 602
Annelids per m²
25000
20000
15000
10000
5000
0
1
10
10²
10³
10⁴
10⁵
SBF Concentration (µg/g dry wt)
Near-Field
Far-Field

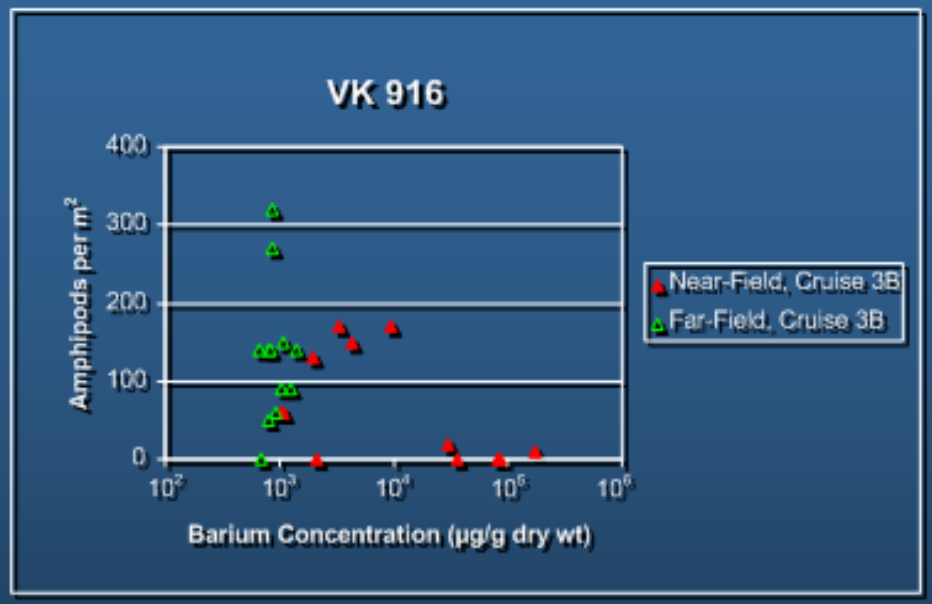

MC 292
Annelids per m²
25000
20000
15000
10000
5000
0
1
10
10²
10³
10⁴
10⁵
SBF Concentration (µg/g dry wt)
Near-Field
Far-Field

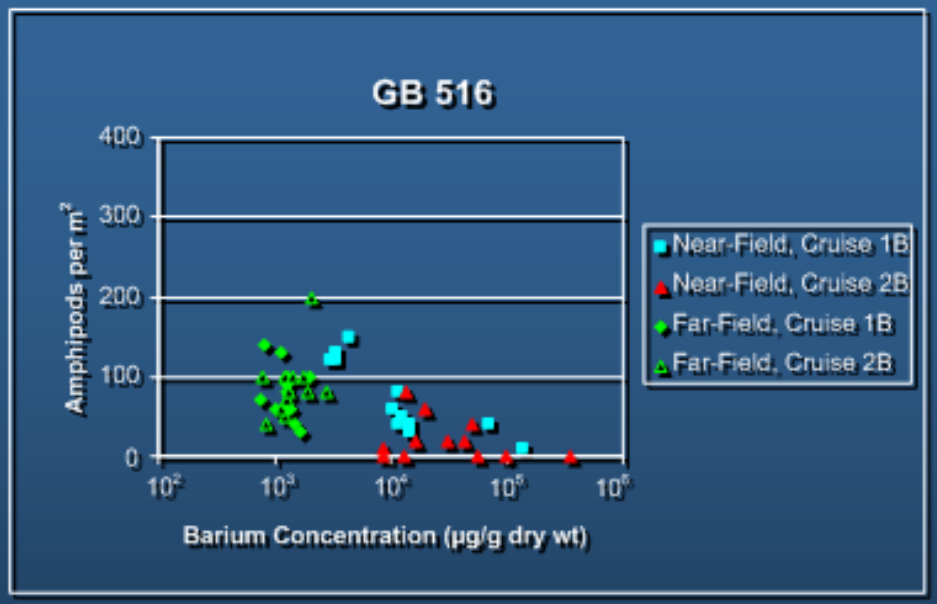
Gastropods

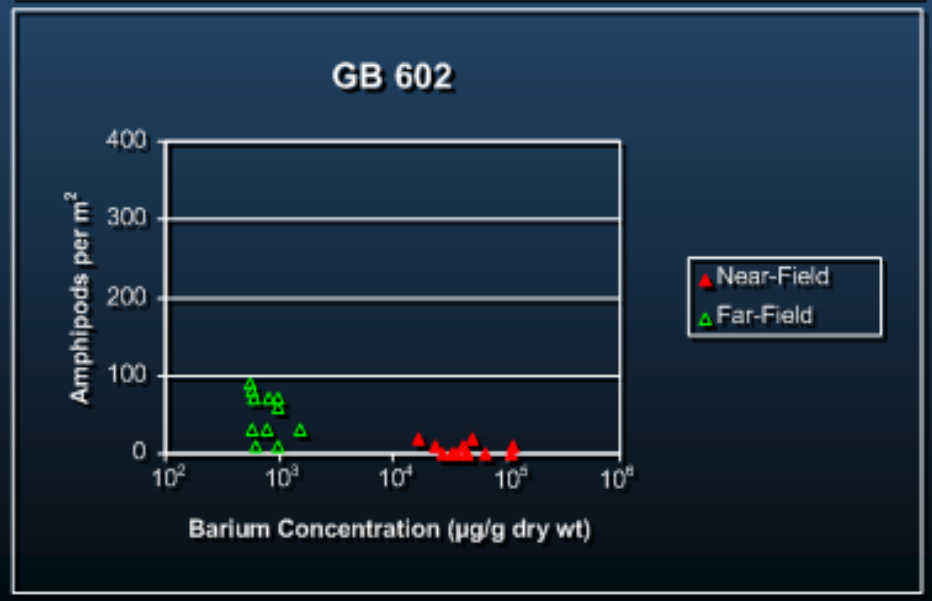

Barium
Gastropods per m2
20000
15000
10000
5000
0
10^3
10^4
10^5
10^6
Barium Concentration (ug/g dry wt)
VK916-Cr3 NF
GB516-Cr1 NF
GB516-Cr2 NF
GB602-Cr2 NF
MC292-Cr2 NF

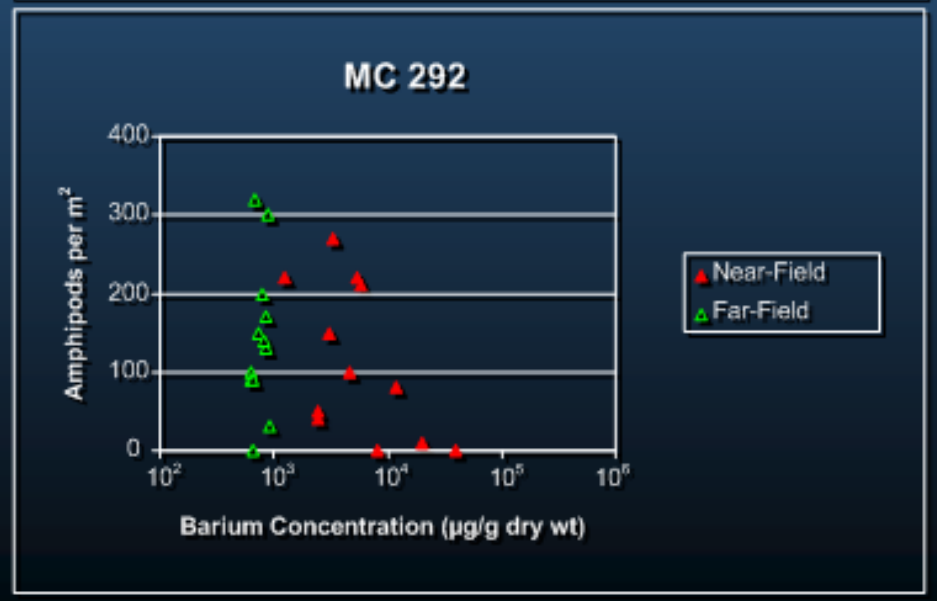

Synthetic Based Fluids
Gastropods per m2
20000
15000
10000
5000
0
1
10
10^2
10^3
10^4
10^5
SBF Concentration (ug/g dry wt)
VK916-Cr3 NF
GB516-Cr1 NF
GB516-Cr2 NF
GB602-Cr2 NF
MC292-Cr2 NF

Amphipods


VK 916
Amphipods per m²
400
300
200
100
0
10²
10³
10⁴
10⁵
10⁶
Barium Concentration (µg/g dry wt)
Near-Field, Cruise 3B
Far-Field, Cruise 3B

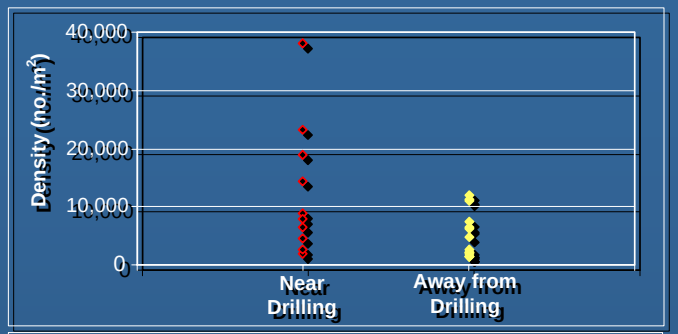

GB 516
Amphipods per m²
400
300
200
100
0
10²
10³
10⁴
10⁵
10⁶
Barium Concentration (µg/g dry wt)
Near-Field, Cruise 1B
Near-Field, Cruise 2B
Far-Field, Cruise 1B
Far-Field, Cruise 2B


GB 602
Amphipods per m²
400
300
200
100
0
10²
10³
10⁴
10⁵
10⁶
Barium Concentration (µg/g dry wt)
Near-Field
Far-Field

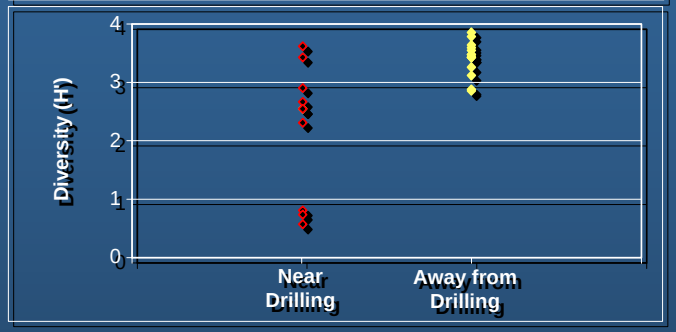

MC 292
Amphipods per m²
400
300
200
100
0
10²
10³
10⁴
10⁵
10⁶
Barium Concentration (µg/g dry wt)
Near-Field
Far-Field

Detailed Taxonomic Analysis

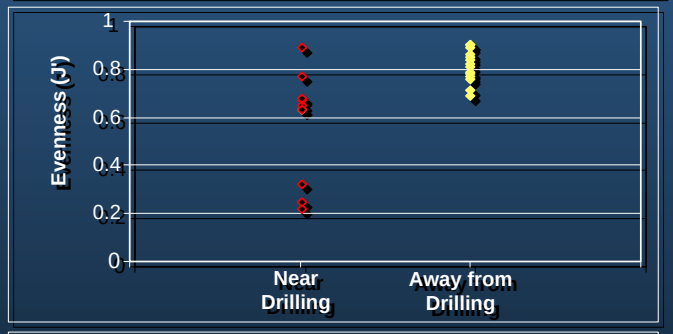
- Compared with stations away from drilling, some stations near drilling
  - lower diversity
  - lower evenness
  - lower richness indices
- Species composition varied in relation to both geographic location and drilling impacts
  - areas most likely affected by drilling were dominated by high abundances of one or a few deposit-feeding species, including known pollution indicators



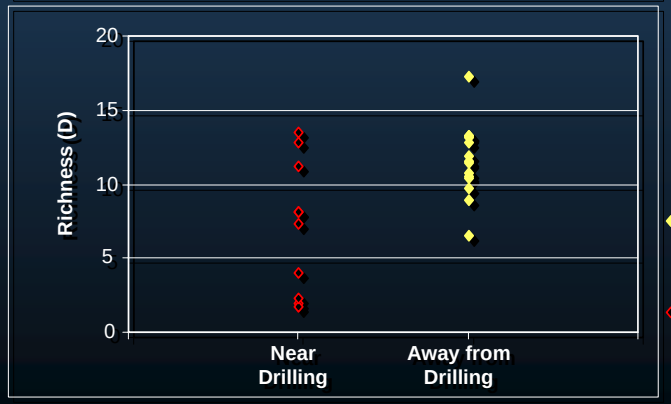
(a) Density



(b) Diversity



(c) Evenness



(d) Richness

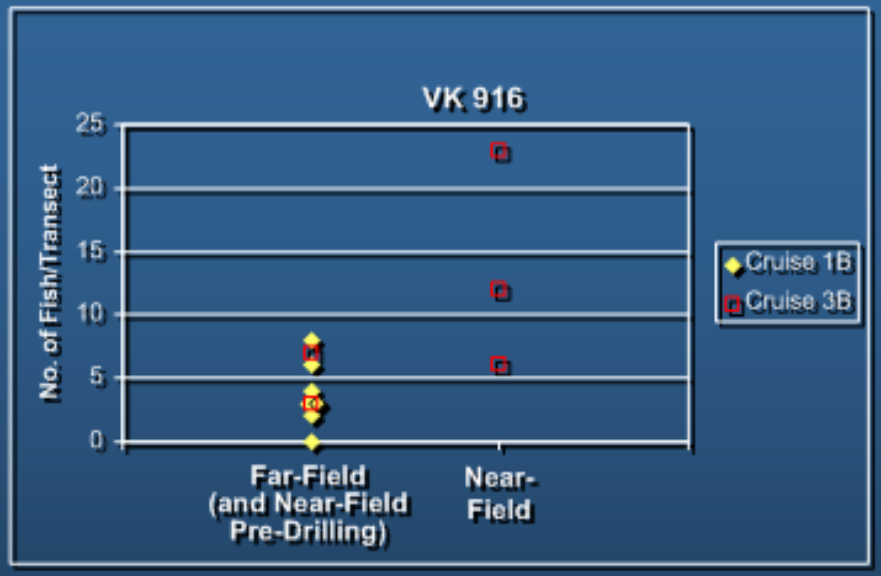
◆ "Away from Drilling" = all far-field stations plus near-field pre-drilling stations at VK 916

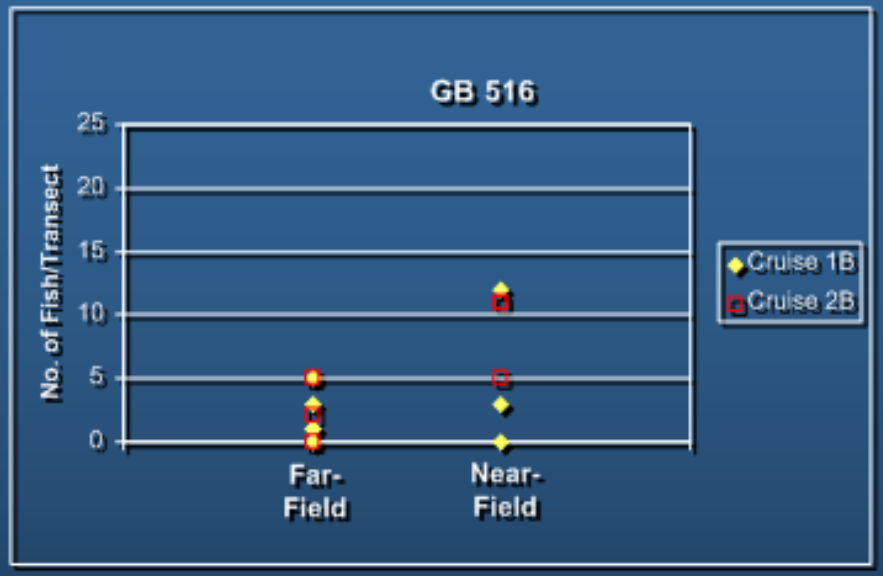
◇ "Near Drilling" = all near-field stations at GB 516, GB 602, and MC 292, plus near-field post-drilling stations at VK 916

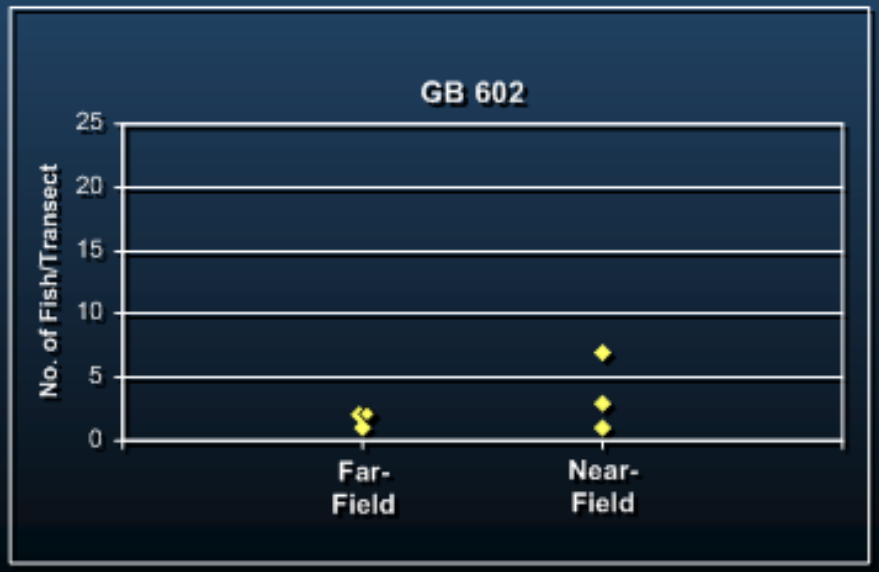
Megafauna

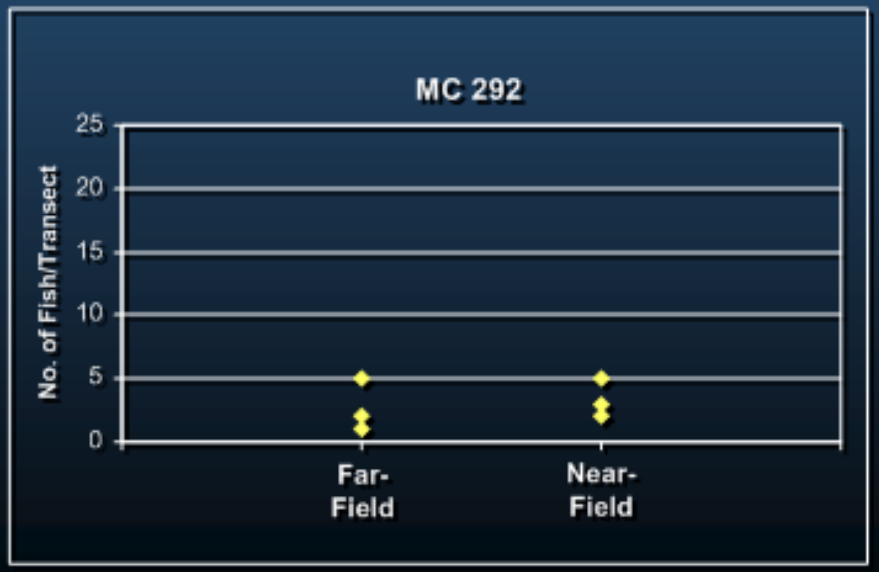
- Megafauna at two near-field sites (VK 916 and GB 516)
  - Increased fish densities
  - Reduced ophiuroid densities

Fish

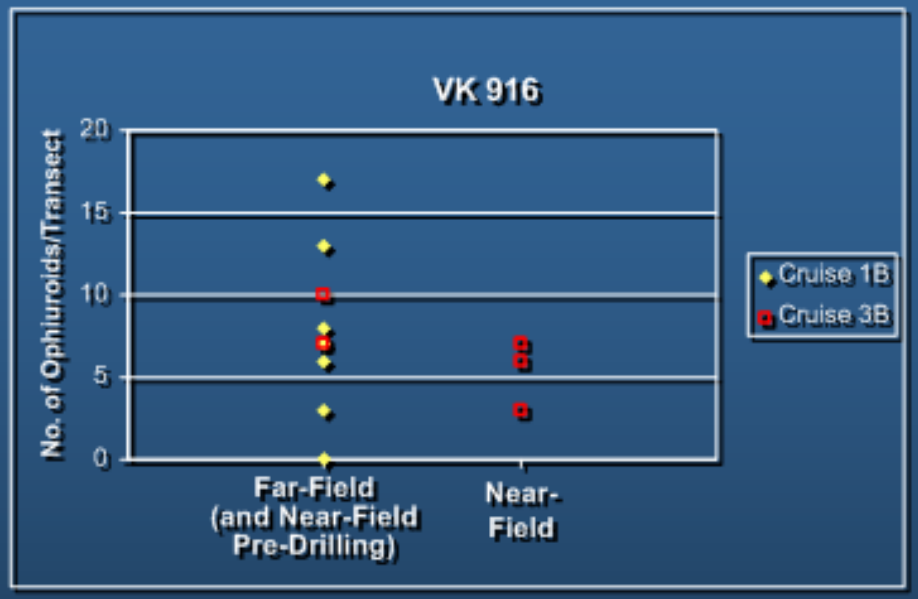

VK 916
No. of Fish/Transect
25
20
15
10
5
0
Far-Field (and Near-Field Pre-Drilling)
Near-Field
Cruise 1B
Cruise 3B

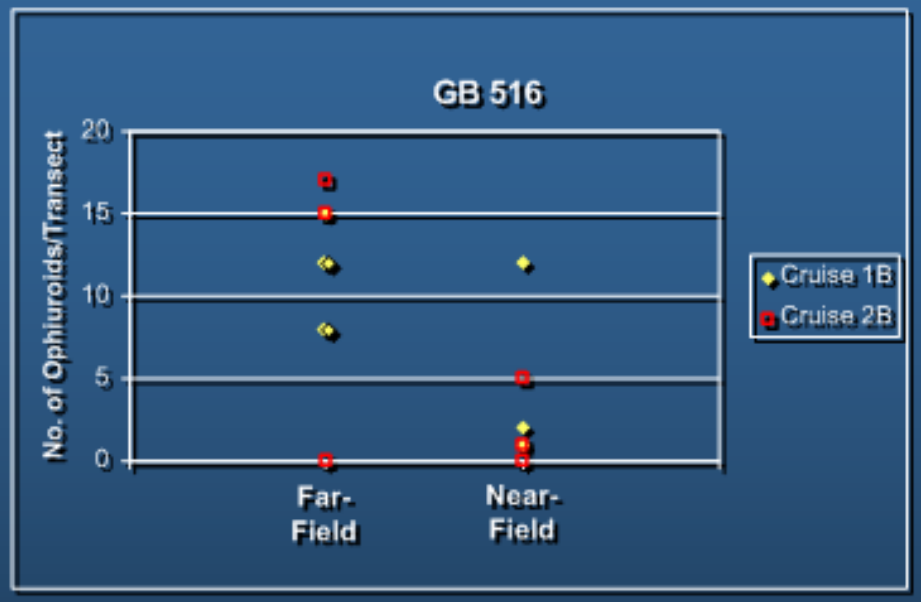

GB 516
No. of Fish/Transect
25
20
15
10
5
0
Far-Field
Near-Field
Cruise 1B
Cruise 2B


GB 602
No. of Fish/Transect
25
20
15
10
5
0
Far-Field
Near-Field

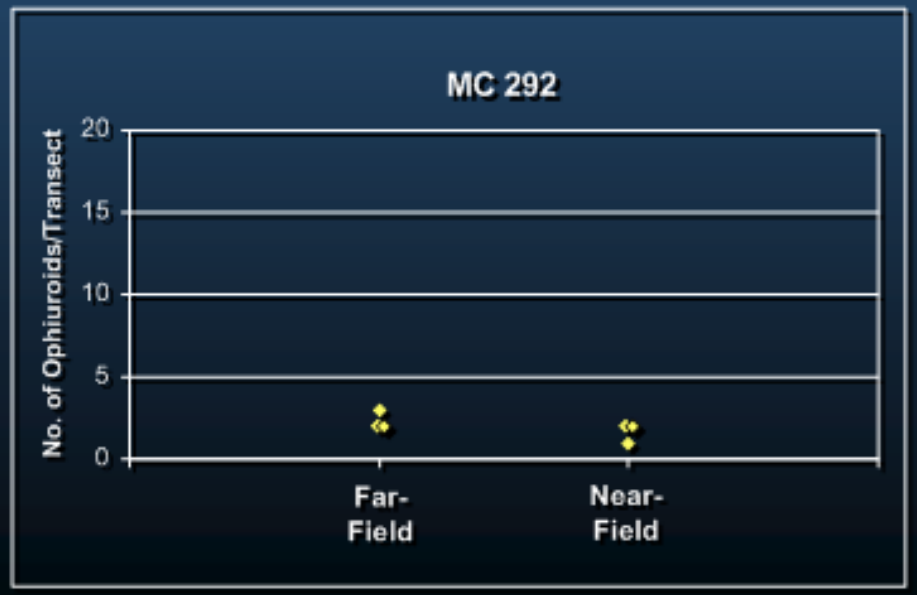

MC 292
No. of Fish/Transect
25
20
15
10
5
0
Far-Field
Near-Field

Ophiuroids


VK 916
No. of Ophiuroids/Transect
20
15
10
5
0
Far-Field (and Near-Field Pre-Drilling)
Near-Field
Cruise 1B
Cruise 3B


GB 516
No. of Ophiuroids/Transect
20
15
10
5
0
Far-Field
Near-Field
Cruise 1B
Cruise 2B

GB 602
No. of Ophiuroids/Transect
20
15
10
5
0
Far-Field
Near-Field


MC 292
No. of Ophiuroids/Transect
20
15
10
5
0
Far-Field
Near-Field

Impacts

- In the near field, impacts were patchy
- Some near-field stations showed conditions similar to those at the far-field sites
- Impacts generally were less extensive and less severe at post-exploration sites than at post-development sites
- Geophysically detected deposits of muds and cuttings persist for >5 years
- Anchor scars may persist for >14 years