Deep Life

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Stretching deep biosphere: deeper and deeper

Subseafloor biosphere stretched 7 → >2450 mbsf through 60 years

Table 1. Bacterial titer of sediment at top and bottom of cores collected at different Mid-Pacific (MP) stations.

Station number	Location of Station		Water depth	Length of core	Type of sediment	Bacterial titer*	
	Latitude	Longitude				Top	Bottom
MP	N	W	m	cm			
3–1	20°51′	127°09·9′	4390	747	Red clay	3	0
5–3	14°22·1′	133°06·8′	5300	40	Red clay	4	2
7–2	12°47·5′	134°26·4′	4758	106	Globigerina ooze	1	1
10–2	4°37·2′	140°00·3′	4365	89	Globigerina ooze	1	1
15–1	10°43·5′	145°53·2′	4987	92	Volcanic ash	4	2
17–2	14°38·3′	151°58·4′	5942	122	Red clay	3	3
20–2	20°27·0′	154°55·1′	3825	96	Red clay	4	2
21–2	20°47·0′	159°59·0′	4484	145	Red clay	4	4
25–E	19°02′	169°44′	1759	77	Globigerina ooze	4	4
27–2	19°35′	171°50′	3750	88	Globigerina ooze	3	3
30–1	18°27′	173°14′	3709	71	Red clay	2	2
33–H	17°53′	174°27′	1707	55	Globigerina ooze	2	1
33–L	17°51′	174°17′	1720	43	Globigerina ooze	4	1
35–1	19°21′	174°58′	4841	75	Red clay	4	4
35–2	19°02′	174°58′	3935	363	Red clay	3	3
36–1	16°48′	176°27′	5032	319	Globigerina ooze	4	3
37–1	17°06′	177°18′	5032	275	Globigerina ooze	4	2
38–1	19°02′	177°18′	4712	366	Red clay	3	0
40–1	15°35·	177°30′	4121	387	Red clay	3	0

* 0 = No viable bacteria demonstrated in 1·0 gram of wet sediment.
1 = At least 10 but < 100 viable bacteria per gram of wet sediment.
2 = At least 100 but < 1,000 viable bacteria per gram of wet sediment.
3 = At least 1,000 but < 10,000 viable bacteria per gram of wet sediment.
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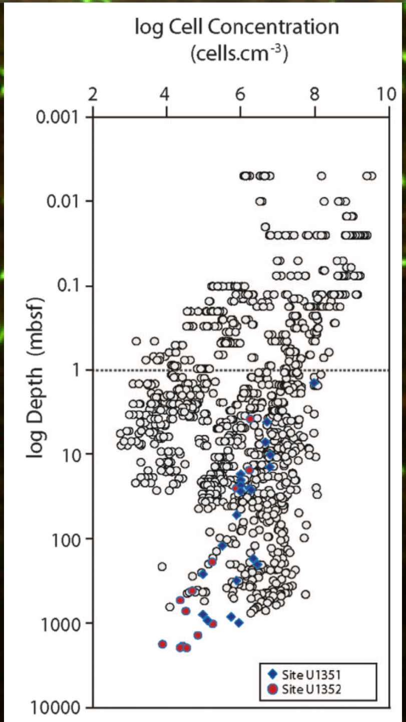
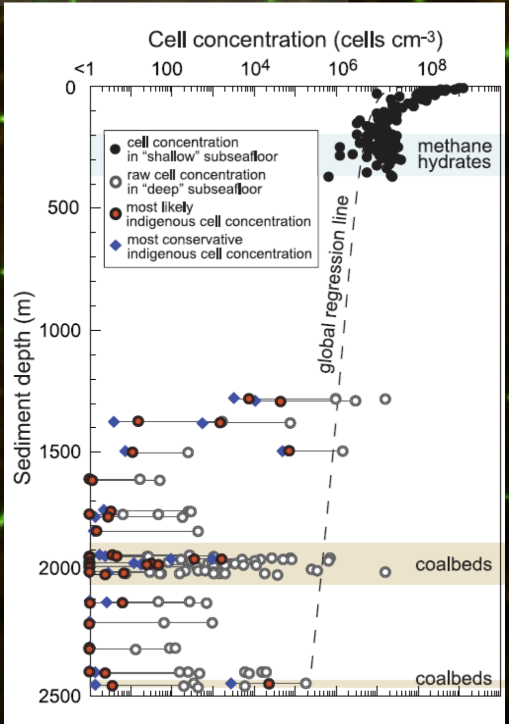
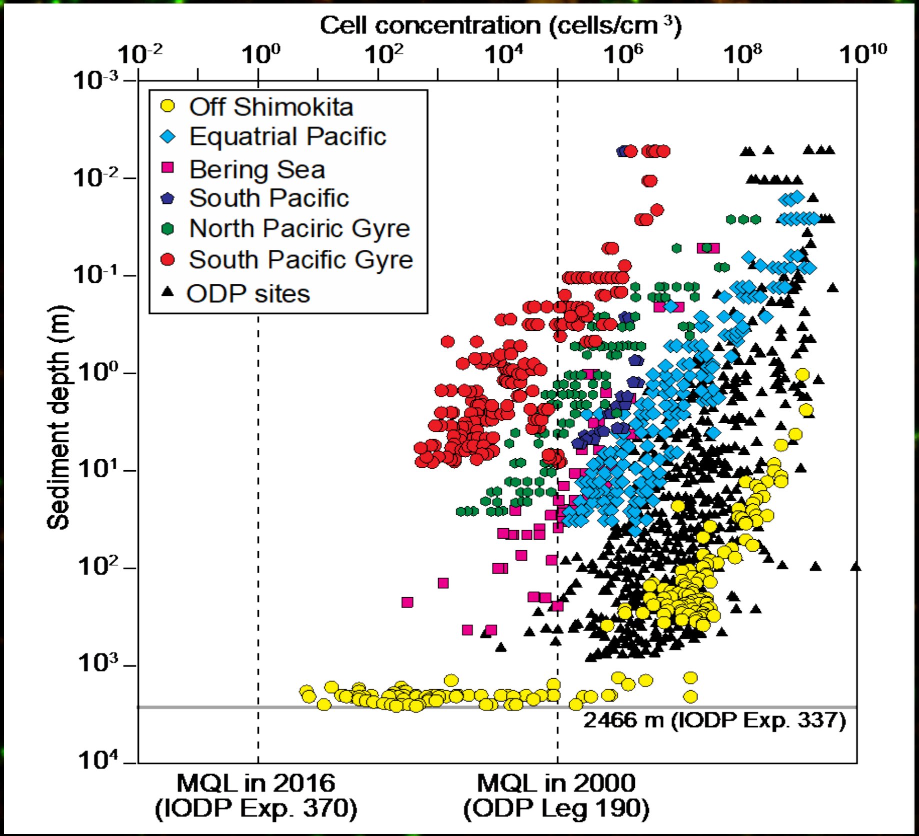
Morita and Zobell, 1955



Ciobanu et al, 2014



Inagaki et al, 2015



Modified from Kallmeyer et al., PNAS, 2012 and Inagaki et al., Science, 2015.

International Ocean Discovery Program New Science Plan 2013-2023

Biosphere Frontiers

***Challenge 6:* What are the limits of life in the subseafloor?**

***Challenge 5:* What are the origin, composition, and global significance of subseafloor communities?**

***Challenge 7:* How sensitive are ecosystems and biodiversity to environmental change?**

…ON THE DEEP BIOSPHERE/BIOSPHERE FRONTIERS

Program	#	EXPEDITION
IODP (Discovery)	371	Tasman Frontier Subduction Initiation and Paleogene Climate
	370	Temperature Limit of the Deep Biosphere off Muroto
	369	Australia Cretaceous Climate and Tectonics
	368	South China Sea Rifted Margin B
	367	South China Sea Rifted Margin A
	366	Mariana Convergent Margin
	365	NanTroSEIZE Shallow Megasplay Long-Term Borehole Monitoring System
	364	Chicxulub K-T Impact Crater
	363	Western Pacific Warm Pool
	362	Sumatra Seismogenic Zone
	362T	Transit / Hole U1473 Remediation
	361	Southern African Climates and Agulhas Current Density Profile
	360	SW Indian Ridge Lower Crust/Moho
	359	Maldives Monsoon and Sea Level
	357	Atlantis Massif Seafloor Processes: Serpentinization and Life
	356	Indonesian Throughflow
	355	Arabian Sea Monsoon (CPP)
	354	Bengal Fan
	353	Indian Monsoon Rainfall
	352	Izu Bonin Mariana: Forearc
	351	Izu Bonin Mariana: Arc Origins
	350	Izu Bonin Mariana: Rear Arc
	349	South China Sea Tectonics
IODP (Integrated)	348	Nankai Trough Seismogenic Zone Experiment Stage 3, Plate Boundary Deep Riser
	347	Baltic Sea Basin Paleoenvironment
	346	Asian Monsoon
	345	Hess Deep Plutonic Crust
	344	Costa Rica Seismogenesis Project, Program A Stage 2 (CRISP-A2)
	343	Japan Trench Fast Earthquake Drilling Project (JFAST)
	342	Paleogene Newfoundland Sediment Drifts
	341S	Simple Cabled Instrument for Measuring Parameters In situ (SCIMPI) and Hole 858G CORK replacement
	341	Southern Alaska Margin: Interactions of tectonics, climate, and sedimentation
	340T	Atlantis Massif Oceanic Core Complex: Velocity, porosity, and impedance contrasts within the domal core of Atlantis Massif
	340	Lesser Antilles Volcanism and Landslides: Drilling volcanic landslides deposits and volcanoclastic sediments in the Lesser Antilles arc
	339	Mediterranean Outflow: Environmental significance of the Mediterranean Outflow Water
	338	NanTroSEIZE Stage 3: Plate Boundary Deep Riser 2
	336	Mid-Atlantic Ridge Microbiology
	337	Deep Coalbed Biosphere off Shimokita
	335	Superfast Spreading Rate Crust 4
	334	Costa Rica Seismogenesis Project (CRISP)
	333	NanTroSEIZE Stage 2: Subduction Inputs 2 and Heat Flow
	332	NanTroSEIZE Stage 2: Riserless Observatory
	331	DEEP HOT BIOSPHERE
	330	Louisville Seamount Trail
	329	South Pacific Gyre Subseafloor Life
	328	Cascadia Subduction Zone ACORK Observatory
	327	Juan de Fuca Hydrogeology
	326	NanTroSEIZE Stage 3: Plate Boundary Deep Riser 1
	325	Great Barrier Reef environmental changes
	324	Shatsky Rise
	323	Pliocene-Pleistocene paleoceanography and climate history of the Bering Sea
	322	NanTroSEIZE Stage 2: Subduction inputs
	321T	Juan de Fuca Hydrogeology
	321	Pacific Equatorial Age Transect
	320T	USIO Sea Trials and Assessment of Readiness Transit (START): Ontong Java Plateau
	320	Pacific Equatorial Age Transect
	319	NanTroSEIZE Stage 2: Riser/Riserless Observatory 1
	318	Wilkes Land
	317	Canterbury Basin
	316	NanTroSEIZE Project Stage 1 - Thrust Faults
	315	NanTroSEIZE Project Stage 1 Mega-Splay Riser Pilot
	314	NanTroSEIZE Project Stage 1 - LWD Transect
	313	New Jersey Shallow Shelf
	312	Superfast Spreading Rate Crust 3
	311	Cascadia Margin Gas Hydrates
	310	Tahiti Sea Level
	309	Superfast Spreading Rate Crust 2
	308	Gulf of Mexico Hydrogeology
	307	Porcupine Basin Carbonate Mounds
	306	North Atlantic Climate 2
	305	Ocean Core Complex Formation, Atlantis Massif 2
	304	Oceanic Core Complex Formation, Atlantis Massif 1
	303	North Atlantic Climate 1
	302	Arctic Coring Expedition (ACEX)
	301	Juan de Fuca Hydrogeology
	301T	Costa Rica Hydrogeology

2013 - 2023

357: Atlantis Massif Seafloor Processes: Serpentinization and Life (2015, ESO)

370: Temperature Limit of the Deep Biosphere off Muroto (2016, CDEX)

385: Guaymas Basin Tectonics and Biosphere (2019, JRSO)

More drilling has brought additional (technical) challenges

->EXAMPLE: NEED TO DETECT THE ABSENCE (!) OF LIFE

The things we have learned, and remaining challenges;

- *Microbes persist or survive even in various extreme subseafloor environments.*
    - *Deep (~2.5 km below the seafloor)*
    - *Scarce in nutrients (ultra-oligotrophic South Pacific Gyre)*
    - *Old (~100 Ma sediment)*
    - *Hot (~120 degrees Celsius)*
- *Microbes are LIVING and as diverse as in ocean water and terrestrial soils.*

- *We haven't identified the "end of the biosphere".*
- *We have started to capture the species richness, but we are still far from understanding the global significance of subseafloor communities*
- *Also, the sensitivity of ecosystems to environmental change is not known*

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Inter-theme cooperation is the key for further exploration!!

Biosphere Frontiers

Challenge 6: What are the limits of life in the subseafloor?

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Challenge 7: How sensitive are ecosystems and biodiversity to environmental change?

Earth in Motion

Challenge 13: What properties and processes govern the flow and storage of carbon in the subseafloor?

Challenge 14: How do fluids link subseafloor tectonic, thermal, and biogeochemical processes?

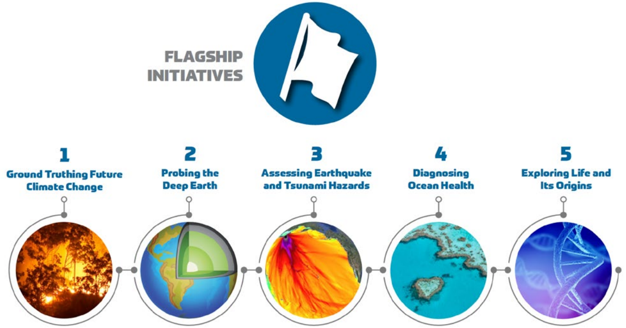
Climate and Ocean Change

Challenge 1: How does Earth's climate system respond to elevated levels of atmospheric CO_2?

Earth Connections

Challenge 10: What are the mechanisms, magnitude, and history of chemical exchanges between the oceanic crust and seawater?

Many links to Biosphere exploration



- Life nourished by the dynamic motion of Earth
- Ancient DNA dictating past Earth environments
- Effects of environmental change on life
- Impact of life activities on Earth's environment
- Life-driven global element cycles
- The response of life to drastic geological events

The subseafloor hosts a large variety of living environments. Understanding the response of life to spatial and temporal changes in environmental factors (e.g. pressure, temperature, space, nutrients, energy) will bring key knowledge about the requirements and limits of life on Earth and in the Universe.

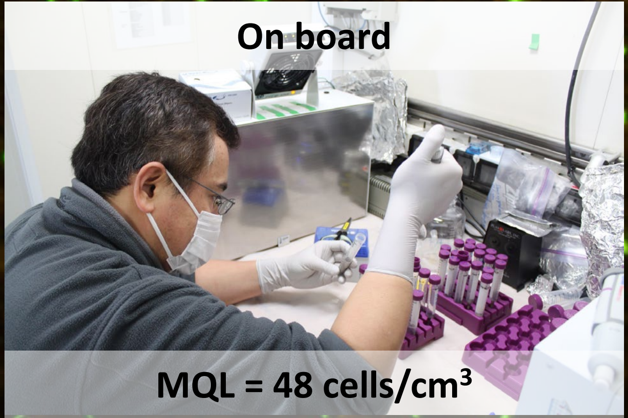
Sample quality and rigorous QAQC is a matter for us

Quality assurance (QA): Process or set of processes used to measure and assure the quality of an experiment

➡ Procedure to avoid/trace contamination

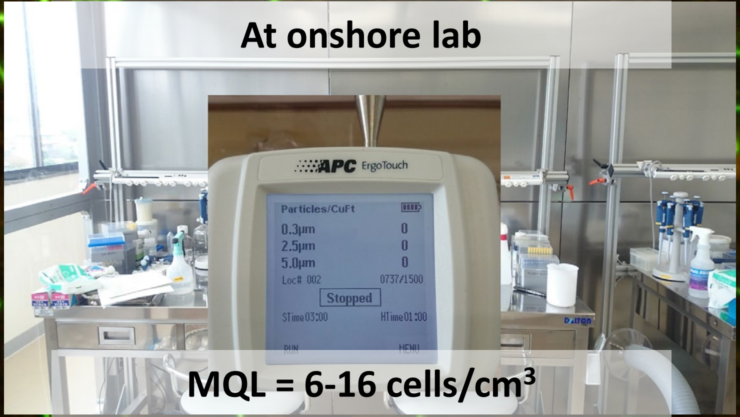
Quality control (QC): Process of ensuring experiment and measures meet experimental expectations

➡ Contamination check, determination of confidence interval (e.g. minimum quantification limit)



On board

MQL = 48 cells/cm^3



At onshore lab

MQL = 6-16 cells/cm^3

What can we do / What is still challenging?

- Samples with >10^6 ~ 10^7 cells/cm^3
  - Metagenomics
  - Cell counts
  - Activity measurements
  - Electron microscopy observation
  - Molecular analysis
- Samples with >100 cells/cm^3
  - Cell counts
  - Activity measurements
  - Electron microscopy observation
  - Molecular analysis
- For very low biomass <100 cells/cm^3
  - Cell counts
  - （Maybe) Activity measurements

Obtainable information will decrease as biomass shrinks, but still manageable to some degree!!

SOD-Microbiology needs to be (very) flexible

<u>Always requesting Whole Round Cores limits our chance</u>

- *Flexible sampling need to be pursued*
- *Don't be flexible for quality and traceability of contamination*
- *Targeted sampling will be the key to address unanswered question*

<u>Flexible cruise will be great, Limiting number is challenging, but we can maximize our science!!</u>

- *Paired sampling (inter-theme) will bring new endeavor*
- *Further inter-theme co-working is the key*

Deep Life

Thank you for your attention!!