



# INTERNATIONAL OCEAN DRILLING PROGRAMME

## PROPOSAL 1109-FULL

Go Beyond the Limit (GBL) drilling: How, why,  
and where does life become extinct, and what  
lies beyond the limit?

# IODP<sup>3</sup> Proposal Cover Sheet

## Proposal Title:

Go Beyond the Limit (GBL) drilling: How, why, and where does life become extinct, and what lies beyond the limit?

## Broad Geographic Area of the Proposal

Western Pacific

## Project Abstract

Go Beyond the Limit (GBL) drilling will test how, why, and where seafloor life becomes extinct, and what physical-chemical conditions define the abiotic domain. We propose to recover a continuous sedimentary section on the Nankai Trough floor (SW Japan), where high heat flow and thick sediments allow us to traverse the putative upper temperature limit for life (>160°C) within ~1–1.4 km of drilling. Building on D/V Chikyu Expedition 370 (T-Limit), which approached but did not definitively reach the limit, our primary site (GBL-08) targets a predictable, largely diffusion-dominated thermal gradient and projected basement temperatures of ~190°C. Three alternate sites (GBL-10/13/19; projected basement temperatures of ~175–240°C) provide contingency and enable assessment of spatial variability and hydrogeologic complexity.

A key advance in this Full Proposal is an explicit operational framework for recognising the biosphere–abiotic boundary. We will define the boundary using convergent evidence from independent proxies (cell abundance/morphology; DNA/RNA/protein and lipid biomarkers; tracer-based contamination control and blanks; and isotopic/biogeochemical fingerprints), with pre-defined detection limits, reproducibility requirements, and a decision matrix that distinguishes in situ signals from contamination and post-recovery artefacts. Shipboard incubations will be used only as secondary, tightly controlled tests of metabolic potential and will not be the primary criterion for defining the boundary.

To maximise interpretability at extremely low biomass, we will validate all novel/alternative detection methods prior to drilling using existing high-temperature D/V Chikyu core material (e.g., Expeditions 337 and 370). These include ultrasensitive sequencing/detection approaches (e.g., nanogap/nanopore-based workflows targeting degraded or non-canonical biomolecules) and complementary non-sequencing assays for independent verification.

Continuous coring to 1180 mbsf at GBL-08, coupled with logging-while-drilling (resistivity, natural gamma, sonic where feasible) and downhole temperature/pressure measurements, will provide the physical context needed to link habitability to mineral transformations, fluid flow, pressure regime, and diagenetic reactions. An optional borehole temperature monitoring system (re-entry with UWTV) will be co-designed with the operator and implemented if feasible.

GBL will deliver the first well-constrained, multi-proxy map of the transition from active deep biosphere to abiotic sediments across an unprecedented temperature range, advancing IODP3 2050 priorities on habitability, Earth system processes, and planetary analogs.

## Scientific Objectives

Objective A – Identify and explain the biosphere–abiotic transition (BAT) in diffusion-dominated seafloor sediments that cross into the >160°C regime.

- Test whether the boundary is (A1) a sharp thermodynamic limit, (A2) a cryptic persistence of biomass/biosignatures below conventional detection, or (A3) an apparent boundary shaped by dormant/endospore states and/or relic biomolecules.

Objective B – Quantify controls on microbial community filtering and biosignature persistence across the thermal gradient.

- Determine whether community composition and biosignature survival correlate more strongly with present-day temperature or with time–temperature trajectories (T<sub>max</sub>, warming rate, and time-above-threshold), using thermal modeling anchored by downhole measurements and vitrinite reflectance.

Objective C – Define the handover from biologically mediated reactions to abiotic diagenetic/metamorphic processes beyond the boundary.

- Integrate microbiology with pore-water chemistry, mineral/organic transformations, and reaction-transport constraints to identify where microbial influence becomes negligible.

## Science Communication Plain Language Summary

Life exists far below the seafloor, living in tiny pores between sediment grains. As sediments are buried and slowly heated over millions of years, conditions eventually become too hot for life. We know that microbes can live in the deep seabed up to about 120°C, but we do not yet know exactly where life stops, how quickly it disappears, or what traces remain after it is gone.

Go Beyond the Limit (GBL) will drill in the Nankai Trough off southwest Japan, where high natural heat flow and thick sediments create a stable temperature gradient—like a natural “slow cooker” —from cold seafloor conditions down to temperatures above 160°C. This is a key range that has not been recovered as a long, continuous sediment record before.

By recovering clean, continuous cores and measuring temperature, chemistry, and rock properties, we will test the boundary between the “biosphere” (where life is present and/or active) and an “abiotic” zone (where life is absent and chemical reactions dominate). To avoid false positives in very low-biomass sediments, we will use strict contamination tracing and will only accept biological detection when multiple independent methods agree. We will also run carefully controlled incubation experiments (including stable-isotope and radiotracer approaches) to detect extremely low metabolic activity and to evaluate whether microbes near the boundary are alive, dormant (including spores), or only preserved as relic molecules.

An important twist is that temperature is not only what we measure today: sediments have a thermal history. We will reconstruct how long each layer has been exposed to high temperatures (maximum temperature, warming rate, and time above key thresholds) and test whether this history controls microbial survival and biosignature persistence.

Understanding Earth’s temperature limit for life matters beyond microbiology. It improves how we interpret chemical “signatures of life” in ancient rocks, guides the search for life in extreme environments on other worlds, and clarifies how deep Earth processes influence the cycling of carbon, sulfur, and other elements.