Exploring deep microbial life in the planetary interior: What are the limits of habitability?

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Over the past two decades, our understanding of the deep subseafloor biosphere has significantly expanded through scientific ocean drilling. Since the first deep biosphere-dedicated ODP Leg 201 off Peru in 2002, numerous microbiological and biogeochemical studies at various oceanographic locations have been accomplished, demonstrating that microbial cells are present almost everywhere beneath the ocean floor. These results also indicate that deeply buried microbial communities have long persisted and survived under the geophysically and energetically challenging environments within the Earth's interior over geologic time. Numerous molecular (DNA, lipids, enzymes) ecological studies revealed that subseafloor deep microbial communities consist mainly of previously uncultured and hence physiologically unknown species and play significant ecological roles in biogeochemical element cycling. It means, deep subseafloor life may have uniquely adapted to and evolved within the dark and low-energy interface between surface and subsurface on the planet Earth.

Recent technological developments are underpinning the continuous expansion of our scientific knowledge, especially for exploring the limits of planetary habitability in the Earth interior. For example, during IODP Expedition 329, the occurrence of dissolved oxygen and aerobic microbial communities was discovered in the entire sediment column of the ultra-oligotrophic South Pacific Gyre, indicating no limits to microbial life in sedimentary environments of the open ocean. In addition, deep riser-drilling during IODP Expedition 337 demonstrated that indigenous microbial communities occur in ~2.5 km-deep coal-bearing sediments and play important biogeochemical roles in carbon cycling. Furthermore, a recent IODP Expedition 370 aims to understand the temperature limit of the deep subseafloor biosphere in the protothrust zone of the Nankai subduction system, and the important mission of super-clean microbiological sampling was successfully accomplished. These efforts and challenges of international research communities to explore the biosphere frontiers will elucidate how the deep biosphere coevolve with the planet Earth and how the Earth's habitability will respond to some drastic environmental changes that may occur at the planetary scale in the near to deep future.