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Meeting report

Trench Connection

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'Trench Connection' was the first international symposium focusing primarily on the hadal zone (depths greater than 6000 m). It was held at the University of Tokyo's Atmosphere and Ocean Research Institute in November 2010. The symposium was successful in having attracted an international collective of scientists and engineers to discuss the latest developments in the exploration and understanding of the deepest environments on Earth. The symposium sessions were categorized into three themes: (i) new deep-submergence technology; (ii) trench ecology and evolution; and (iii) the physical environment. Recent technological developments have overcome the challenges of accessing the extreme depths, which have in turn prompted an international renewed interest in researching physical and biological aspects of the hadal ecosystems. This bringing together of international participants from different disciplines led to healthy discussions throughout the symposium, providing potential opportunities and realizations of where the future of unravelling hadal ecology lies. Hadal science is still at relatively rudimentary levels compared with those of shallower marine environments; however, it became apparent at the symposium that it is now an ever-expanding scientific field.

Keywords: hadal zone; trench ecology; deep-sea biology; deep submergence technology

1. INTRODUCTION

The hadal zone, which comprises primarily of ocean trenches, represents the deepest marine habitat on Earth (6000–11 000 m), accounting for the bottom 45 per cent of the full ocean depth range. Far from being devoid of life as originally perceived, we are now aware that the trenches host a wide variety and abundance of life with a high degree of endemism. Ever since these extreme depths were first sampled in the last century, most biological investigations comprised opportunistic and non-standardized recovery of hadal fauna and sediments using small core/grab samples and trawls [1]. Although these campaigns were pioneering in deep-sea sampling at that time, the methods used were limited in efficiency and as a result, our knowledge of the ecological functioning and structure of the hadal community remains rudimentary. However, the technical challenges previously associated with extreme hydrostatic pressure and distance from the surface no longer exist, heralding a new era in the exploration of this most poorly understood marine ecosystem.

The trenches represent a disjunct cluster of deep habitats and therefore cannot be interpreted as a mere continuation of the continental slopes and abyssal plains. The hadal environment also adds several unique attributes. For example, hadal fauna survive on the fringes of two extremes; hydrostatic pressure and remoteness from surface-derived food supply, the understanding of which will provide great insight into global depth-related trends. Also, there is compelling evidence to suggest the trenches act as carbon sinks by topography-induced accumulation of surface-derived particulate organic carbon. Furthermore, in an age when ocean conservation is becoming ever more pertinent, pursuing scientific endeavour in all marine habitats is paramount, as even the deepest depths are not exempt from anthropogenic impact or a changing climate.

The renewed interest in hadal environments has appeared rapidly in the last decade, mostly in the United States, the UK and Japan. One such project called HADEEP (HADal Environments and Education Programme; 2006–2011) was awarded to collaborators from the Universities of Aberdeen (UK) and Tokyo (Japan) by the Nippon Foundation (Japan). Over the course of these 5 years, it became evident just how many researchers in universities and institutes around the world were either pursuing hadal science or had a vested interest in doing so. To channel these efforts and bring together scientists and engineers interested in trench biology, ecology and technology, the first international symposium on hadal science entitled 'Trench Connection' was held at the Atmosphere and Ocean Research Institute at Tokyo University (10–13 November 2010). The symposium integrated approximately 70 participants from six different countries, in which 33 oral presentations were made across three main themes: (i) new technology, (ii) hadal ecology and evolution, and (ii) physical environment.

2. MAKING THE TRENCH CONNECTION

(a) *New full ocean depth technology*

The opening keynote speech was delivered by Andy Bowen (Woods Hole Oceanographic Institute) who described the latest full ocean depth capabilities: the Hybrid Remotely Operated Vehicle *Nereus* [2]. This vehicle has recently completed field trials in the deepest place on Earth, Challenger Deep (10 900 m), and offers new and unprecedented access to these deep environments. Its ability to perform both acoustic and video transects, as well as the recovery of organisms and sediment samples, now provides the potential to map, observe and quantify the distribution of hadal fauna *in situ* with the capacity for examinations of comparative physiology, genetics, biochemistry and environmental parameters.

Technology developed within the HADEEP project was also presented, which represented a lower cost method of visualizing and recovering hadal fauna [3]. These free-fall imaging landers and traps have, in the last 4 years, been deployed in five hadal trenches around the Pacific Rim to depths as deep as 10 000 m. The images and samples obtained have led to the description of many new species and first-time

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observations of several taxa, and paved the way for the beginnings of the first inter-trench faunal distribution and phylogeographic studies attempted at these depths.

These new methods of accessing the trenches were complemented by a presentation outlining recent developments in the miniaturization of *in situ* chemical and biochemical analysers, presented by Tatsuhiro Fukuba (University of Tokyo). Based on microfluidic technology, these newly developed sensors offer a unique capability in microbiology by detecting micro-organisms via polymerase chain reaction and intracellular adenosine triphosphate techniques *in situ*. They also add a new capability for detecting geological features such as hydrothermal vents through the detection and real-time monitoring of dissolved manganese ion.

It became evident over the course of the meeting that a combination of these technologies has the potential to provide for the first time, the means for researchers to systematically explore these deep habitats and quantify hadal community structure, distribution and biomass.

(b) *Ecology and evolution at the extreme depths*

The ecology sessions focused on the latest findings within trenches and the extension of depth-related trends to hadal depths. For example, T.F. (University of Aberdeen) presented spatial variability in the distribution of endemic snailfishes observed in three hadal trenches, which has recently prompted a reappraisal of the occurrence of hadal fish assemblages [4]. Hsin-Ming Yeh (Fisheries Research Institute of Taiwan) described the faunal zonation of demersal fishes in the waters adjacent to Japan, from the coastal zones to the hadal zone. He concluded that the fish community structure coincided with regional hydrography, more so than topography. By contrast, A.J.J. (University of Aberdeen) presented recent research from the Kermadec Trench (southwest Pacific) that showed the amphipod community structure within the trench is distinctively different from the neighbouring abyssal plains, and proposed topography as the likely explanation [5].

A compelling comparison of meiofaunal abundance and biomass between two northwest Pacific trenches was presented by Motohiro Shimanaga (Kumamoto University). He showed a direct correlation between elevated abundance and biomass in the eutrophic Kuril trench compared with the oligotrophic Ryukyu trench, which emphasizes the importance of geography and surface primary production even in the deepest habitats [6]. The relationship between hadal fauna and the shallower zones was challenged once more by Takuro Nunoura (JAMSTEC) who found that although the pelagic microbial communities in the Marianas and Ogasawara trenches were distinctly different, the Ogasawara communities were quite similar to the continental margin, whereas the Marianas community was seemingly unique. This suggests that the proximity to major continental land masses (which can vary greatly among trenches) may be influencing microbial community structure in the hado-pelagic zone. He concluded by proposing that these data represent a topography-induced 'trench biosphere'. Furthermore, a keynote speech by Hiroshi Kitazato from JAMSTEC (Japan Agency for Marine-Earth Science and Technology) outlined more of the latest research being undertaken by Japanese researchers. For example, continuing the trench biosphere idea, he described the endemism and importance of benthic foraminifera in the trenches, which are all soft-shelled owing to the extreme hydrostatic pressure [7]. To conclude, he described the most recent and upcoming research campaigns to test the hypothesis that trenches act as large carbon sinks in the oceans and that material cycling in the trenches may be an important driver of trench endemism.

Evolutionary aspects were covered by two taxa: holothurians and amphipods. Andrey Gebruk (Russian Academy of Sciences) focused on the holothurian genus *Elpidia*, which is a predominant hadal group. He examined the evolutionary relationships of all 22 known species and showed a distinctive grouping of the trench species. Furthermore, most species are unique to single trenches, although some occur in closely neighbouring trenches. Similar findings from phylogenetic analysis of scavenging amphipods were presented by Stuart Piertney (University of Aberdeen), who suggested that amphipod populations may be structured according to depth and that communities exhibit both endemic and cosmopolitan distributions.

(c) *Aspects of the physical environment*

The physical environment sessions were split primarily into physical oceanography and geology. The keynote presentation by Shinzou Fujio (University of Tokyo) showed that recently obtained direct measurements of current velocity and direction have revealed that the large-scale deep-water currents around the trenches off Japan were far more complex than previously anticipated. Although the current generally flows northwards, weaker currents were found over the western flanks than over the eastern flanks. He expanded these observational data with numerical models to show that most of the water flows horizontally towards the Aleutian Trench, consistent with the hypothesis of large upwelling in the northwest Pacific [8].

Kazuya Niato (University of Tokyo) described a new numerical method (distinct element method) to reveal the initial trench-forming processes. He classified the process of plate subduction in three stages as: (i) plate boundary rotation before subduction, (ii) lithospheric slab formation along the plate boundary, and (iii) beginning plate subduction with initial oceanic trench formation.

3. CONCLUSIONS

The Trench Connection Symposium provided an ideal setting for both scientists and engineers to review what is currently known, being investigated and what questions still need addressing with respect to the hadal environment. It provided the opportunity for an international collective to bring together, for the first time, the latest research and hypotheses, methods and technology, and the opportunity to engage across institutes,

countries and scientific disciplines with a common goal.

Hadal science is still very much in its infancy, and there are many avenues awaiting exploration and understanding. Scientifically, the key to this lies both in international collaboration and systematic scientific approach. Historically, hadal research comprised opportunistic sampling 'snap-shots' that has led to limitations in deriving conclusions with confidence, owing mainly to inconsistency in replication, methods, sampling depths and locations undertaken within and between trenches. One of the major conclusions arising from the symposium was the need to perform consistent sampling in multiple trenches to attempt to disentangle processes driven purely by depth (i.e. 'hadal') and the varying characteristics and conditions of individual trenches (i.e. topography, food supply, isolation). While hadal scientific campaigns are still relatively infrequent compared with those sampling at shallower depths, one approach is the exchange of technology and expertise to promote both an international and inter-trench synergy. To achieve this, it was concluded that participants involved in Trench Connection would form an international network with the intention of further meetings and workshops to continue open dialogue and explore future opportunities. In the foreseeable future, we envisaged fulfilling this at the forthcoming World Conference on Marine Biodiversity (September 2011, Aberdeen, UK) and the 13th Deep-Sea Biology Symposium (2012, Wellington, New Zealand).

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