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COMPACT MULTIPURPOSE SUB-SAMPLING AND PROCESSING OF IN-SITU CORES WITH PRESS (PRESSURIZED CORE SUB-SAMPLING AND EXTRUSION SYSTEM)

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ABSTRACT

Understanding the deep biosphere is of great commercial and scientific interest and will contribute to increased knowledge of the environment. If environmentally relevant results are to be obtained the precondition to achieve genuine findings is research in pristine habitat as close as possible to those encountered *in-situ*.

Therefore benthic conditions of sediment structure and gas hydrates, temperature, pressure and bio-geochemistry have to be maintained during the sequences of sampling, retrieval, transfer, storage and downstream analysis.

At the Technische Universität Berlin (TUB) the Pressurized Core Sub-Sampling and Extrusion System (PRESS) was developed in the EU project HYACE/HYACINTH. It enables well-defined sectioning and transfer of drilled pressure-cores [obtained by HYACE Rotary Corer (HRC) and Fugro Pressure Corer (FPC)] into transportation and investigation chambers. Coupled with DeepIsoBUG (University Cardiff, John Parkes) it allows sub-sampling and incubation of coaxial core-sections to examine high-pressure adapted bacteria or remote biogeochemical processes in defined research conditions of the laboratory; all sterile, anaerobic and without depressurisation.

Appraisals of successful PRESS deployments in the Gulf of Mexico, on IODP Expedition 311 and as part of the NGHP expedition 01 demonstrate the general concept to be feasible and useful.

Aided by Deutsche Forschungsgemeinschaft (DFG) TUB is currently working on concepts to downscale the system in order to reduce logistical and financial expenses and, likewise, to enlarge its implementation by requiring less operating space. Redesigning the cutting mechanism shall simultaneously adjust the system to harder cores (*e.g.*, ICDP). Novel transportation chambers for processed sub-samples intend to make the system more attractive for a broad spectrum of users and reduce their interdependence.

Keywords: gas hydrates, pressure coring, in-situ, sampling, sub sampling, microbiology

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NOMENCLATURE

BHA	Bottom-Hole Assembly
DFG	Deutsche Forschungsgemeinschaft
EU	European Union
FPC	Fugro Pressure Corer
HRC	HYACE Rotary Corer
HYACE	HYdrate Autoclave Coring Equipment
HYACINTH	HYACE Tools in New Test on Hydrates
ICDP	International Continental Scientific Drilling Program
MSCL-P	Pressure Multisensor Core Logger (Geotek)
NGHP	Indian National Gas Hydrate Program
PCS	Pressure Core Sampler
PRESS	Pressurized Core Sub-Sampling and Extrusion System
PTCS	Pressure and Temperature Maintaining Coring System
SC	Storage Chamber
STC	manipulator/Shear Transfer Chamber
TUB	Technische Universität Berlin

INTRODUCTION

A core sample, recovered from beneath the land or sea floor, is no longer in pristine condition, due to the enormous pressure change while moving it to the surface, from great depths to atmospheric conditions. As a result mechanical, physical, and chemical properties as well as living conditions for microorganisms of the deep biosphere are significantly altered. In order to investigate highly instable gas hydrates, which decomposes under pressure and temperature change, a suite of research technologies have been developed by TUB and European partners in the EU Project HYACE (Hydrate Autoclave Coring Equipment System) in 1997. The succeeding Project HYACINTH (HYACE Tools in New Test on Hydrates), as well as continuous improvements during various deployments of these prototypes were considerably successful and made the tools more and more reliable.

The investigation of the pressurized cores with various measurements, such as X-ray, gamma ray, and p-wave, revealed numerous details of gas hydrates which have been unknown before and cannot be obtained with unpressurized cores. PRESS, the sub-sampling system developed by TU Berlin, is furthermore able to produce well defined pressurized sub-sections of anoxic and contamination controllable sub-samples of desired length at a maximum of 25 MPa of operating pressure. These sub-sections can either be transferred under pressure into transportation chambers or are preprocessed with the pressurized cutter and diverter unit (DeepIso Bug, Uni. Cardiff) for microbiological research at highest pressures.

The next logical step of development is extending the applicability of the pressure coring system to pressure related phenomena other than gas hydrates. Possible future applications include, but are not limited to, research in shales and other tight formations, CO_2-sequestration, oil and gas exploration, coalbed methane, and microbiology of the deep biosphere.

To meet the corresponding requirements and to incorporate the experiences from previous expeditions the pressure coring system needs to be redesigned to adapt it to the new applications.

HYACINTH PRESSURE CORING [1]

Depressurization and changes in temperature during conventional coring changes the majority of core properties. This holds especially true for gas hydrates that will decompose rapidly, which prompted a few scientific and engineering research groups in the U.S., Japan, and Europe to develop methods and tools of pressure sampling and monitoring in order to achieve in-situ findings in pristine habitat.

In 1997 an EU research project and consortium, HYACE, developed *inter alia*, two novel down hole pressure coring systems; the motor driven HRC (Hyace Rotary Corer) for hard formations, and a percussion corer FPC (Fugro Pressure Corer) for softer formations.

These systems were technically evaluated in 2000. The HRC was tested in the deep ocean on board of RV Joides Resolution on ODP Leg 191 at the beginning of 2001, and the FPC was tested during two Fugro offshore service missions.

During the HYACE follow-up project HYACINTH further improvements were made, and the partners additionally developed a pressurized subsampling device (Hans Amann, TU Berlin) and a suite of pressurized microbiological research equipment (John Parkes, now University of Cardiff). With the results of HYACE and HYACINTH, new technical systems of in-situ research, process investigations of unchanged, pristine conditions of the deep sea floor became feasible.

State of the Art

Apart from gas hydrate research and few exceptions, where pressure coring is inevitable to gather reliable results, most scientist so far come to terms with ex-situ methods; but ex-situ methods can give limited answers only concerning gas hydrate associated micro biosphere and many other properties, such as equilibrium of gases, fluids and solids, phase boundaries, wettability, integrity of the mechanical structure, *etc.* To date, investigations of fundamental lithological issues have remained largely disconnected from applied proven studies using in situ pressure drilling technologies, although the integration and correlation between the very diverse data sets of standard core measurement and pressure core data makes it difficult to extrapolate anything reliably beyond the borehole.

To bring pristine benthic conditions to the controlled situation of the lab and to evaluate them, under quasi in-situ conditions, three main steps are necessary:

i) actual autoclave sampling from the deep biosphere,
ii) sub-sampling and core transfer under in-situ conditions,
iii) pressurized lab analysis and technical process test methods.

Autoclave Coring Tools

Down-hole autoclave coring tools worth mentioning are ODP's Pressure Core Sampler (PCS) from the U.S., and the Japanese Pressure and Temperature Maintaining Coring System (PTCS). In contrast to the more flexible and economic HYACINTH wire line tools, such as the Hyace Rotary Corer (HRC), or the Fugro Pressure Corer (FPC) the PTCS and PCS cannot be interfaced with core transfer or subsequent processing tools. Consequently their applications and advantages are limited to pressurized core retrieval only.

HYACINTH coring tools [2]

Two types of wireline pressure coring tools were developed in the EU-funded HYACE/ HYACINTH programs: A percussion corer and a rotary corer, which were designed to cut and recover core in a range of lithologies where gas hydrate bearing formations might exist. Both tools have been designed for use with the same IODP bottom-hole assembly (BHA) as the PCS and follow similar operational procedures on the rig floor. The tools are deployed in the open drill string, which is then closed to lower the tools on the wireline while pumping and rotating. After the pressure core is collected the corer is recovered to the surface, as fast as practically possible. In order to prevent the autoclaves from warming up they are continuously cooled until they are removed from the tools and placed in a refrigerated place for analysis.

HYCINTH core transfer

In order to remove the core from the pressure corer autoclave, the autoclave is connected to the manipulator/shear transfer chamber (STC) with quick-clamps and then pressure-balanced with the autoclave before opening the ball valves and transferring the pressure core together with mechanical top into the STC. Coupled with Geotek´s Pressure Multisensor Core Logger (MSCL-P) nondestructive measurements can be conducted. For sub-sampling or further analysis cores are transferred into storage chambers (SC) for storage at in-situ pressure and temperature-controlled conditions (5-7°C) for shore-based analyses.

When transferring a core the bottom half, containing the sediment, is severed from the re-usable mechanical top half by clipping the liner with the shear-blades.

HYACINTH core logging

Access for scientific surveying and remote analysis of a sample in a high pressure vessel is confined to remote monitoring methods from outside of the pressure vessel. Material properties of pressure resistant and cost effective vessels on the one side, transmission of penetrating observation rays and sufficient resolution of core structure investigation on the other side, oppose each other. Although pressure cores are particularly valuable for providing accurate methane volumes for gas hydrate concentration calculations, nondestructive measurements made before or during the depressurization process can provide additional information on the nature and distribution of gas hydrate within the sediment and rare data on near-in-situ physical properties of gas-hydrate-bearing sediments.

The Geotek MSCL-P is an automated measurement system for the measurement of acoustic P-wave velocity, gamma ray attenuation, and X-ray image data on HYACINTH pressure cores under pressures up to 25 MPa. The MSCL-P pressure chamber is constructed of aluminum and contains an internal set of ultrasonic transducers. X-ray and gamma ray sources and detectors are situated outside of the pressure chamber. The system moves pressurized HYACINTH cores incrementally past these sensors under computer control allowing detailed gamma density and acoustic velocity profiles to be obtained rapidly and automatically along the core as well as creating automated full-core X-ray image montages.

HYACINTH sub-sampling [3]

Whereas pressurized coring for scientific drilling is slowly advancing there are only limited methods and tools available to sub-sample and subsequently investigate these samples from the deep and high pressure exposed sea floor and its deep underground.

PRESS, the sub-sampling system is able to cut the HYACINTH pressure cores radial into sections of desired length [Fig.s 1 and 2].

Figure 1 Sectioning a HYACINTH pressure core inside a reefer container with PRESS

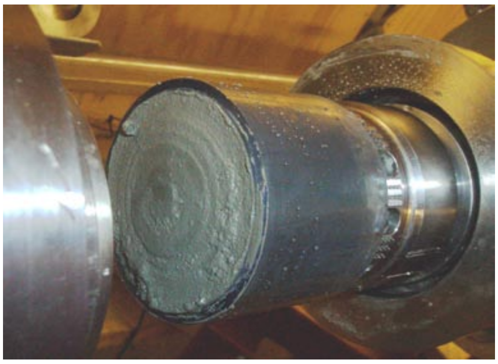

Figure 2 Depressurized core section after cutting with PRESS

These whole round subsections can either be transferred into transportation and investigation chambers for worldwide shipment to other laboratories or are the feed material for pressure dependent geo-microbiological sub-sampling.

Contamination control of the pristine core material is a prerequisite and an additional requirement to establish veridical process data on the formation and the decay of gas hydrates in the deep sea floor, but most necessary for geo-microbiological research as in-situ phenomena.

Swarf free liner cutting, controlled sterilization of hazardous parts and sterilized off-cutting of all potentially contaminated exterior core parts was improved and investigated during the progress of development and could minimize the peril of contamination.

Axial extrusion of the very center of the core produces undisturbed core plugs from the down-hole core as sterile, anoxic, high pressure input feed for the cutter and diverter unit (DeepIso Bug, Uni. Cardiff) [Fig. 3]

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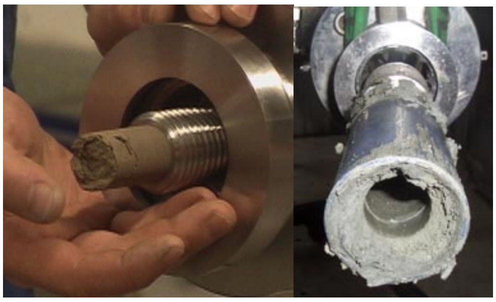

Figure 3 Depressurized axial core plug extrusion with PRESS (l: core plug; r: extruded core section)

Camera monitoring during the operation aids sample selection and confirms successful sample transfer [Fig. 4].

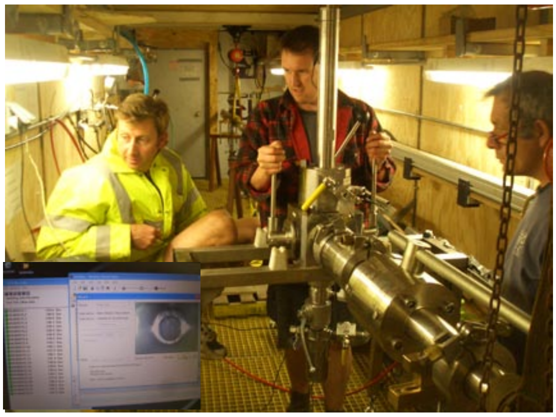

Figure 4 PRESS coupled with DeepIso Bug, video observed sub-sampling of the pressure core plug

Liquid medium in the pressure vessels enables samples to be slurred and then transferred via a transition adapter into a number of high-pressure vessels (max 100 MPa). These can be incubated under a range of conditions (different media, pressures, temperatures *etc.*) thereby enriching a range of different high-pressure adapted bacteria (piezophiles) or study biogeochemical processes at high pressure, such as rates of activity using radio-tracers. Finally, pure cultures can be obtained from positive enrichments within a high-pressure isolation chamber for further study and characterisation.

All systems, well interfaced and pressure safety certified, according to the European pressure vessel regulation 97/23/EC, were successfully used in April and May 2005. A subsequent deployment as part of the NGHP expedition 01 in November 2006 substantiated the usability of the system and could successfully accommodate the demand for pristine deep marine sediment samples by using reliable investigation methods.

Several pressurized microbiological cultivation chambers were achieved and open up new dimensions of applied in-situ deep biosphere science.

Initial results seem promising, showing consistently higher cell numbers to be obtained under elevated pressure (up to 78 MPa) for a number of different enrichment media when compared to 1 bar incubation [4].

PERSPECTIVE

Climate change, dwindling resources and over-consumption result in immediate demand for sustainable resource allocation, habitat conservation and claim for new technologies and prospects for damage-containment. Understanding the deep biosphere may help to define potential hazards, significant regional and global earth flux components, the limits of life on Earth, potentially allows useful organisms for biotechnology to be identified, and will contribute to increased knowledge of the environment.

Within DFG projects TUB currently works on concepts to scale down the system in size and weight and to optimize components to effectively reduces logistical and financial expenses and enlarges the field of application.

It is proposed to extend the range of applications for the rotary pressure corer and the sub-sampling and transfer system to all types of sediments and rocks and to various new operations in other pressure related fields of research such as unconventional gas exploration (coalbed methane, tight gas, gas hydrate), CO_2 sequestration, and microbiology of the deep biosphere. Merging redundant and analogous procedures shall enhance the handling of the tool set and likewise enlarge their implementation to make them more efficient or scale down their immense proportion to reduce logistical and financial expenses. Reducing the PRESS dimensions to a possible minimum comprises, *inter alia*, its implementation on drilling platforms. Expedient enhancement of an overall solution for pressure core retrieval, process and investigation will open the way for an on-site, all-purpose, in-situ complete equipment. The faster a core is processed, the better – even when dealing with pressure and temperature controlled core material.

The proposed assembly would allow for executing the whole operation of coring, non-destructive measurement, pre-processing and transfer into the storage chamber. Extensive post-cruise processing and interim storage would be dispensable. Cores could be entirely arranged in transport and investigation vessels for worldwide shipping within hours after retrieval [Fig 5].

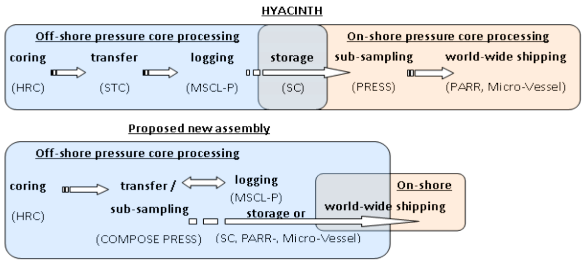

Figure 5 Comparison between current HYACINTH system and proposed new assembly

Advanced design, improved functioning, high performance materials and safety engineering continue to guide further technology developments and will meet the requirements of new fields of applications.

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