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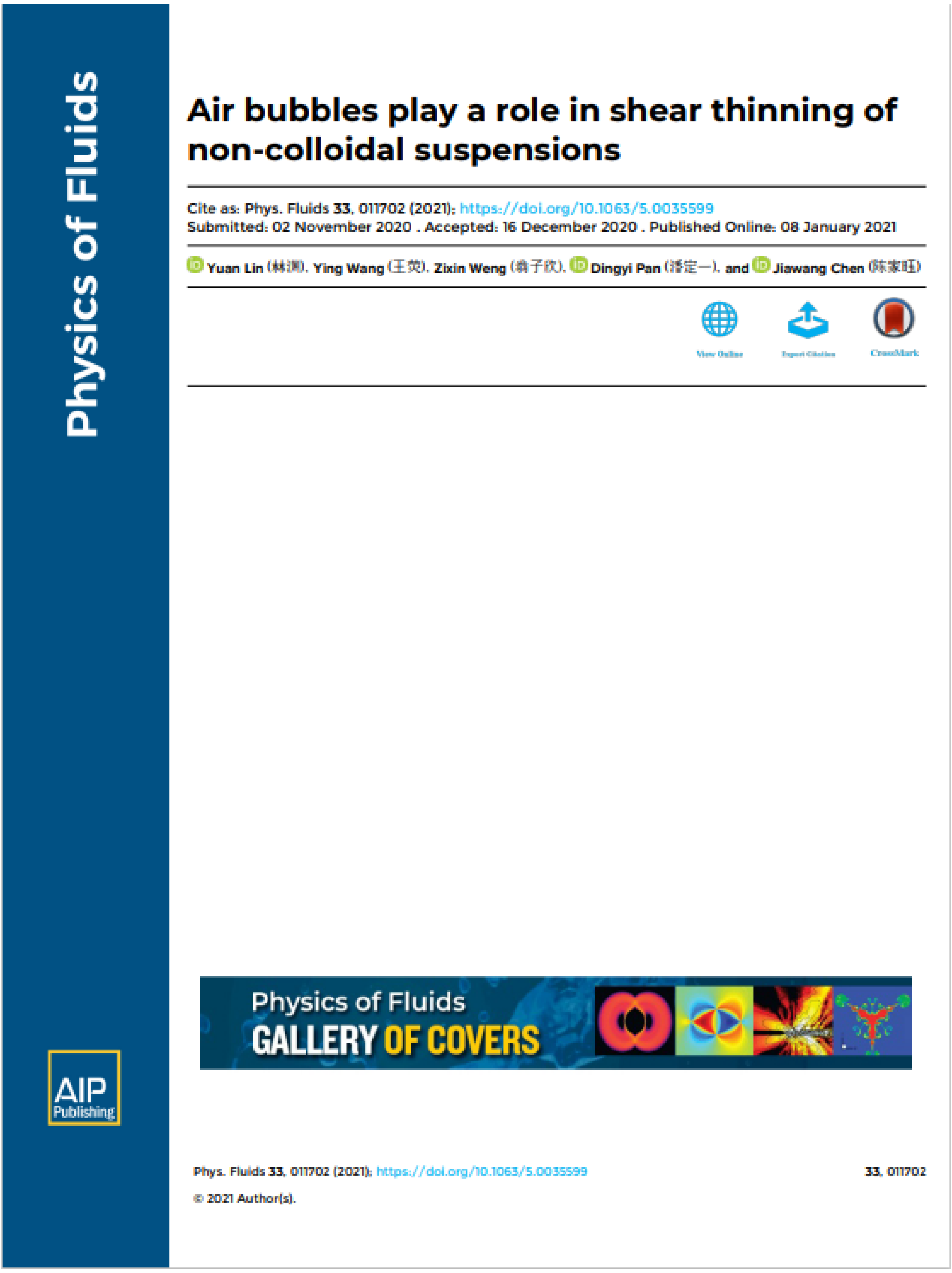
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Air bubbles play a role in shear thinning of non-colloidal suspensions

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Nitin Agarwala,
National Maritime Foundation, India

*CORRESPONDENCE
Jiawang Chen
jwwang@zju.edu.cn
Yuan Lin
samylin@zju.edu.cn

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Advances and development in sampling techniques for marine water resources: a comprehensive review

Ying Wang[1], Jiawang Chen[2,3*], Jin Guo[1], Zhenwu Yu[1], Yuan Lin[3*] and Yuhong Wang[1]

[1]Institute of Ocean Engineering and Technology, Ocean College, Zhejiang University, Zhoushan, China, [2]Donghai Laboratory, Zhoushan, China, [3]Ocean Research Center of Zhoushan, Zhejiang University, Zhoushan, China

Marine water resources (including seawater and pore-water) provide important information for understanding the marine environment, studying marine organisms, and developing marine resources. Obtaining high-quality marine water samples is significant to marine scientific research and monitoring of marine resources. Since the 20th century, marine water resources sampling technology has become the key research direction of marine equipment. In order to have a comprehensive understanding of marine water resource sampling technology, promote the development of marine water resource sampling technology, and obtain high-quality marine water samples, this paper summarizes the current development status of the sampling technology of marine water resources from the aspects of research and application. This paper first provides an overview of seawater and pore water sampling techniques. The two sampling technologies are categorized and discussed according to different sampling means, and the advantages of different sampling means are compared. We also found similarities between seawater and pore water sampling means. Then, a comprehensive analysis of existing technologies and equipment reveals the development trend of marine water resources sampling technology, for example, the need for high temporal and spatial accuracy in sampling, etc. Finally, it explores the challenges facing deep-sea water sampling technology regarding future research, development and equipment industrialization. These reviews not only help researchers better understand the current development of marine water sampling technologies but also provide an important reference for the future development of marine water sampling technology, which provides guidance and support for in-depth marine scientific research and effective use of marine resources.

KEYWORDS
marine water resources, seawater sampling techniques, pore-water sampling techniques, marine sampler development, deep-sea applications

[4] **Wang Y**, Chen J, Guo J, et al. Design and study of a deep-sea multi-depth in-situ pore water pressure-retaining sampler[J]. Marine Georesources & Geotechnology, 2022, 41(12): 1370-8.

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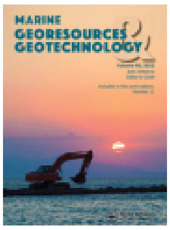

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Design and study of a deep-sea multi-depth in-situ pore water pressure-retaining sampler

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Pore water pressure maintaining sampler for deployment on deep-sea ROV-Jellyfish

Ying Wang [a], Jin Guo [a,d], Xinghui Tan [a], Jiawang Chen [a,b,c,*], Yuping Fang [a], Wei Wang [a,d], Yongqiang Ge [a]

[a] Institute of Ocean Engineering and Technology, Ocean College, Zhejiang University, Zhoushan, 316021, China
[b] Donghai Laboratory, Zhoushan, 316021, China
[c] Ocean Research Center of Zhoushan, Zhejiang University, Zhoushan, 316021, China
[d] Hainan Institute, Zhejiang University, Sanya, 572025, China

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ABSTRACT

Obtaining high-quality pore water samples is of great importance for marine resource investigations. We describe a deep-sea in-situ pore-water pressure-maintaining sampler aboard the heavy-duty ROV-Jellyfish. It can operate at water depths up to 3000 m and acquire 24 different pore-water pressure-holding samples of seafloor sediments with a sampling depth resolution of 2 cm. In this study, the working capacity of the pore water sampler is initially analyzed through structural design and theoretical calculation. The force changes of the integrated system of sampling Rhizons during the penetration of sediments and the extraction of pore water were simulated by the CEL-coupled Euler method in ABAQUS to determine the material and working speed of the integrated system.

Meanwhile, the interaction and diffusion effects at the interface between the sample and deionized water during the pore water sample storage under pressure retention were investigated by the laminar flow and dilute matter diffusion methods in COMSOL. Laboratory experiments were conducted to analyze the effect of 2 cm depth resolution on the maximum sampling volume when obtaining pore water samples at different depths during the sampling process, thus reducing the mutual contamination between pore water samples from adjacent layers. Finally, the sea trials prove the sampler's pressure-holding sealing performance and application performance. Thus, the pore water sampler can carry out more in-depth scientific applications.

1. Introduction

Biogeochemical and geological processes influence deep-sea sediment pore water. Therefore, the composition of pore water reflects the geological state of change in the deep sea (Liu and Peng, 2019). For example, in deep-sea methane seeps, gas hydrates are often identified by detecting anomalies in pore water and surface seawater, such as methane and hydrogen sulfide, to predict the formation and ablation of gas hydrates in sediments (Hu et al., 2020). Therefore, studying pore water sampling in deep-sea sediments is significant in exploring and developing marine hydrocarbon resources (Xu et al., 2018). However, the quality of current pore water testing of seafloor sediment pore water in methane seep areas is to be improved due to the lack of high-quality pore water sampling techniques and subsequent pressure-holding transfer techniques.

Existing pore water sampling methods are usually divided into non-in-situ and in-situ samplers. Non-in-situ sampling is mainly done by pressing, centrifugation, and vacuum filtration (Fanning and Pilson, 1971). The sediment samples removed by centrifugation are well-layered. Therefore, centrifugation does not alter the layered characteristics of the sediment (Barnes, 1973). For sediments with low water content, organic solvents can be added and then centrifuged, but ensure that the added solvents do not affect the content of the ions to be measured. Such sampling methods can lead to changes in the physical and chemical properties of the soil, and the measured data do not exactly match the actual situation, which is not conducive to long-term positioning studies. Therefore, in situ sampling, where the collection equipment is buried directly at the sampling site, is preferred by scientists because of the higher accuracy of the samples obtained.

Pore water in-situ sampler Sayles et al. (1976) proposed an in-situ pore water sampling method using the equilibrium dialysis-Peeper method in 1976. For this method, deionized water and sediment

* Corresponding author. Institute of Ocean Engineering and Technology, Ocean College, Zhejiang University, Zhoushan, 316021, China.
E-mail address: arwang@zju.edu.cn (J. Chen).

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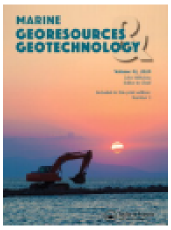

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An *in-situ* portable pore-water sampler for evaluating the vertical distribution in the sediment interface

Ying Wang, Xinghui Tan, Xingshuang Lin, Yuping Fang, Yuan Lin, Jiawang Chen, Yuhong Wang & Yuxia Sun

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Research on In-situ Timing Sampling Device of Pore Water in Deep-Sea Sediments

Ying Wang
Ocean College, Zhejiang University
Zhoushan, China
wy1094948005@163.com

Yongqiang Ge
Ocean College, Zhejiang University
Zhoushan, China
ge_yongqiang@zju.edu.cn

Xingshuang Lin
Ocean College, Zhejiang University
Zhoushan, China
xslin@zju.edu.cn

Yuping Fang
Ocean College, Zhejiang University
Zhoushan, China
fyp19871025@163.com

Jiawang Chen
1.Ocean College, Zhejiang University
Zhoushan, China
2.Hainan Institute, Zhejiang University
Sanya, China
arwang@zju.edu.cn

***Abstract*—The pore water of seafloor sediments is affected by biogeochemistry and geological processes. The study of deep-sea sediment pore water sampling is of great significance to the exploration and development of marine oil and gas resources, especially in the exploration of submarine gas hydrates, which can provide effective geochemical characteristic information. For example, through continuous monitoring of the chemical composition of the deep-sea hydrothermal vent water (such as the concentration of chlorine, calcium, magnesium, iron oxide, pH value, etc.), the changes in the local seafloor crust can be assessed. Therefore, deep-sea sediment pore water is important in marine engineering geology research. In recent years, the new in-situ pore water sampling technology based on osmotic pumps has been developed significantly. The principle of this technology is that the upper part of the sampling device chamber is filled with NaCl and deionized water to form supersaturated brine. The reverse osmosis membrane doesn't allow dissolved salts to pass through, and the salinity difference between the two sides of the membrane encourages water flow from the side with a lower concentration to the side with a higher concentration. Under this osmotic pressure, the pore water flows into the storage pipe. It is a sampler that can work continuously without power and moving parts. It can collect pore water samples independently and reliably. However, because the specific location of the pore water sample collected by the osmotic pump sampler is estimated based on the flow rate and sampling time of the osmotic pump, the equipment has the defect of insufficient time resolution when sampling for a long time. To make up for the lack of insufficient time resolution caused by long sampling time, the final pore water sample with high time resolution can be obtained more accurately. Based on previous work, this study researches the pore water sampling device of osmotic pumps. When sampling the device for a long time, simulate the diffusion process of pore water and discuss its stability. Finally, a timing marking device that can be used in the osmotic pump sampler is designed so that it can be applied to complex deep-sea environments, to can collect comprehensive, long-term, continuous deep-sea pore water data.**

***Index Terms*—sediment pore water, natural gas hydrate exploration, in-situ and long-term sampling**

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I. Introduction

In the vast sea area, seafloor sediments usually contain 20% to 50% water, which is called sediment pore water. With the rapid development of industrialization, the pollution of pore water is becoming more and more serious, and because the marine environment is always in dynamic change, to understand the marine environment more accurately, it is necessary to carry out long-term observation. At present, in scientific research and practical application, sensors for observing marine physical properties (such as temperature) have been able to be deployed in the hydrothermal system for one year, but the development of chemical sensors for long-term deployment (more than one month) is lagging [1]. Automatic samplers using electromechanical systems have been used to monitor lakes and rivers, but only a few have been used in the marine environment [2]. Although the electromechanical system can collect dozens of sample data at a time, for long-term observation of the marine environment, the number of samples is insufficient, and the data points will be particularly discrete [3].

Jannasch [4] et al, assembled three Alzet pumps in the micro electromagnetic pump to form an osmotic pump nitrate analyzer, which can continuously sample for more than one month. The sample flow rate was 8 ml/month (20°C) and the reagent flow rate was 0.7 ml/m. Kastner [5] et al, used two semi-permeable membranes to form a device that can continuously sample for one year. The resolution of the sampling time is about 3 days, and the flow rate is 0.08-0.13ml/d (14-28°C). Chapin [6] et al, used 12 Alzet pumps to form a sample pump and a 2.2ml standard Alzet pump to form a reagent pump. The flow rate was about 0.29ml/d. They were able to work in the low-temperature hydrothermal vent of Juan de FUCA ridge for one year. Jannasch [7] et al, separated two solutions with different salt concentrations by a semi-permeable membrane, keeping the brine in the saturated state.

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[8] **Wang Y**, Guo J, Tan X, et al. Design and Testing of a Multi-Channel In-Situ Sampling System for Marine Microorganisms[C]//ISOPE International Ocean and Polar Engineering Conference, 2024: ISOPE-I-24-035.

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Design and Testing of a Multi-channel In-situ Sampling System for Marine Microorganisms

Ying Wang[a], Jin Guo[a,d], Xinghui Tan[a], Zhenwu Yu[a], Yuan Lin[a], Jiawang Chen[b,c]*
[a] Ocean College, Zhejiang University, Zhoushan, China
[b] Ocean Research Center of Zhoushan, Zhejiang University, Zhoushan, China
[c] Donghai Laboratory, Zhoushan, China
Zhoushan, Zhejiang, China;
[d] Hainan Institute, Zhejiang University, Sanya, China.
*Corresponding author: Jiawang Chen

ABSTRACT

Deep-sea organisms must have produced genes, proteins and secondary metabolites with special functions in the ocean. The study of marine microorganisms begins with obtaining many microbial samples, which is important for microbial research. Although some sampling devices for deep-sea microorganisms have been developed, the study of microbial-specific genes and life processes in the deep sea is still limited due to the small number of samples for time series analysis. This paper designed a marine microbial multi-channel in-situ sampling system to obtain about 70 marine microbial filtered samples and realize the underwater in-situ filtration, in-situ lysis and so on.

KEY WORDS: Marine microorganisms; multi-channel; in-situ sampling; marine technological; environmental monitoring; microbial ecology; sampler innovation.

INTRODUCTION

The ocean is rich in biological and mineral resources, and the development of marine microorganisms and their genetic resources will provide new ways and biological materials for developing new biopharmaceuticals, green chemicals and other bioengineering technologies, which have important scientific research value and development potential (Gao et al., 2019). The metabolism, adaptation and biodiversity of microorganisms in the deep sea are the frontier topics of marine research at home and abroad. Deep-sea organisms must have produced genes, proteins and secondary metabolites with special functions in adapting to the extreme environment of the deep sea (Ottesen et al., 2014). The study of marine microorganisms begins with obtaining a large number of microbial samples, so the development of a marine microbial multi-channel sampler is of great significance to microbial research (Wang et al., 2019). The study of marine microbial multi-channel samplers can enable marine workers to understand better the diversity, spatial and temporal dynamics, and ecological functions of marine microorganisms, which can provide important support for marine environmental monitoring, resource assessment and disaster response and is of great significance to promote the research of marine microbial ecology and environmental science.

Oceanographers at the Monterey Bay Aquarium Research Institute (MBARI) and Woods Hole Oceanographic Institution laboratories in the United States have developed a 1000m-class Environmental Sample Processor (ESP) (Scholin et al., 2009). In situ, gene chip assays for marine microorganisms and toxins were performed. In 2010, they successfully performed quantitative PCR amplification experiments of deep-sea methane oxidation genes using a 4000m-class Environmental Sample Processor (D-ESP) (William et al., 2013). These in situ gene assays depend on microbial enrichment, filtration, lysis and nucleic acid purification processes. A D-ESP integrated deep-sea mass spectrometer has also detected substances in the in situ filtered seawater. This whole set of devices has been applied to the in situ detection of methane seeps at 4000m depth and 800m depth and connected to MBARI's MARS (Monterey Accelerated Research System) seafloor observing network. The University of Hawaii discovered the existence of short-periodic rhythmic processes of ocean surface microorganisms using the ESP system. The University of Hawaii used the ESP system to discover short-period rhythmic processes in marine surface microorganisms. In summary, the results of ESP have greatly promoted scientists' attention to in situ observation in the deep ocean (Fukuba et al., 2021). In China, a set of deep-sea in situ biological experimental devices independently developed by the Institute of Deep-sea Science and Engineering of the Chinese Academy of Sciences (IBSE) can automatically complete seawater filtration, microbial lysis and nucleic acid extraction in the deep-sea environment - Deep-sea microbial in situ nucleic acid collection (MISNic Acid Collections, MISNic Acid), and the deep-sea microbial lysing and nucleic acid extraction (MISNcollections), Collections (MISNAC) (Wei et al., 2020). This device is installed on the Phoenix deep-sea in situ biological research platform and can complete the collection of nucleic acid samples from up to nine different time series. During the Phoenix sea trials in 2019, microbial nucleic acids obtained by MISNAC in consecutive periods revealed microbial

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