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# NordMin PhD Course

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## Seafloor Mineral Resources and Prospects of Deep-Sea Mining:

*Geological, Environmental and Technological Challenges Ahead*



*Temperature probe in a vent structure at Seven Sisters Hydrothermal System, Kolbeinsey Ridge*

**3 - 7 October 2016**

**Centre for Geobiology, University of Bergen, Norway**



UNIVERSITY OF BERGEN  
*Faculty of Mathematics and Natural Sciences*



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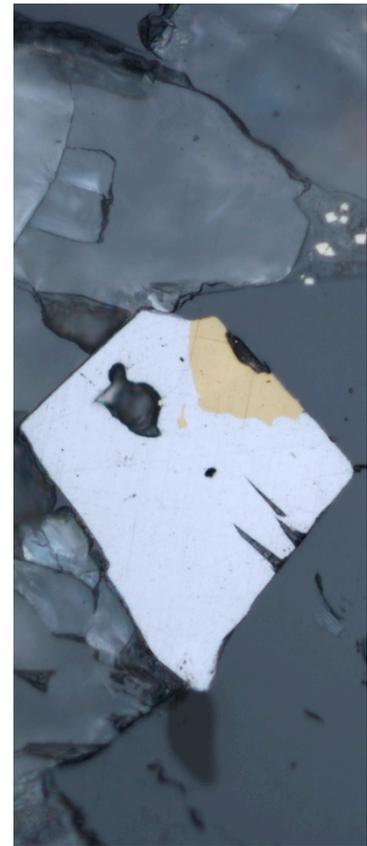
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## Information

Welcome to the 3<sup>rd</sup> NordMin PhD course on Seafloor Mineral Resources and Prospects of Deep Sea Mining, within a Nordic context.

The course will be organized by Centre for Geobiology (CGB) at the University of Bergen, Norway from October 3<sup>rd</sup> to October 7<sup>th</sup>, 2016, as part of the [NordMin project](#) and funded by the Nordic Council of Ministers for the period of 2013–2016. One ambition with the NordMin project is to build a network of excellence in the Nordic countries related to sustainable mining. In this respect, we would like to create platforms and areas where stakeholders meet to discuss mining and mineral extraction from a sustainability perspective. The Nordic context means that issues such as extreme conditions (from a technical perspective and in terms of climate), environmental impact and indigenous people's rights should be addressed together with corporate social responsibility standards and the image of the extractive industry. One such platform will be PhD courses organized in different Nordic countries over the lifespan of the project.



Photomicrograph of galena (PbS) and chalcopyrite (CuFeS) from the Seven Sisters Hydrothermal System in the Kolbeinsey Ridge, field width 50  $\mu\text{m}$   
(© F.Marques / CGB)

## PhD Course

The course will include lectures (L) and practical (P) sessions covering three main aspects of the deep-sea mining: (1) the current knowledge on seafloor hydrothermal systems, their diversity, characteristics, and resource quantification, (2) techniques for seafloor exploration and technology available for exploitation, (3) environmental impacts and nations regulation.

## Scholarships

NordMin will offer up to 20 scholarships to Nordic students. Eligible for scholarships are students from the full value chain of mining, including exploration, mining, mineral processing, metallurgy, environmental aspects, social and societal aspects, and political and economic aspects. A grant of up to **8000 Dkr** will cover travel and accommodation costs. If you are interested in applying for a scholarship, you should apply online using this [form](#) no later than **August 1<sup>st</sup>**. The application should contain a brief description of your PhD topic, CV, and a short summary of the costs (travel, accommodation) for which the scholarship will be used. Successful applicants will be notified on **August 15<sup>th</sup>**. Students applying for a scholarship should withhold from registering until notification from the scholarship board.

# Course Program

## ***Monday 3.10.16 - Seafloor Hydrothermal Systems***

8:00 - 9:00 Reception

9:00 - 10:00 **[L]** Introduction to Seafloor Hydrothermal Systems [CGB: Prof. Rolf B. Pedersen]

10:00 - 12:00 **[L+P]** Diversity of Seafloor Hydrothermal Systems [CGB: Prof. Rolf B. Pedersen]

12:00 - 13:00 Lunch break

13:00 - 14:00 **[L]** From the ocean deep abyss to surface, a tale of 1000 km long divergent plate boundary, the Reykjanes Ridge [Univ. of Iceland: Res. Prof. Ármann Höskuldsson]

The lecture will focus on research along the Reykjanes Ridge from south of Bight fracture zone to the Reykjanes peninsula, Iceland. The Reykjanes Ridge is the longest straight divergent plate boundary on the planet, extending for about 1000 km south from Iceland. The ridge is highly influenced by the presence of the Icelandic mantle plume, expressed by excess magma production and higher heat flow. We shall discuss the general evolution of the Reykjanes Ridge system for the past 20 Ma, current distribution of eruptive vents and geothermal areas and its potential link to volcanogenic massive sulfide ore deposit.

14:00 - 15:00 **[L]** Reykjanes Geothermal Area SW-Iceland, an Analogue to Hydrothermal Systems on the Ocean Floor [Iceland GeoSurvey: Geochem. Dr. Vigdís Hardardóttir]

The lecture will focus on the Reykjanes high-temperature area on the toe of Reykjanes peninsula SW-Iceland. This includes the rifting process, tectonic setting, basaltic host rock, and heat source. Furthermore the fluid composition from 1650–1350 m depth will be compared to the fluid at surface and to black smokers. The boiling process of the ascended geothermal fluid will be discussed along with the precipitation of the sulfide minerals (wurtzite, sphalerite, chalcopyrite and galena) within the boreholes and in the surface pipelines. Kolbeinsey Ridge - Introduction.

15:00 - 17:00 **[L+P]** Seafloor hydrothermal fluids - what controls their chemical composition and metal transport? [CGB: Prof. Eoghan Reeves]

In this lecture we will compare the different types of hydrothermal systems currently known, in terms of the chemical compositions of the hot spring fluids themselves. What do these compositions (dissolved gases, major and minor elements, and metals) of these fluids tell us about the igneous or sedimentary substrate they are circulating through? How do deep and near surface processes influence the styles of metal precipitation on the seafloor? Besides their economic mineral deposit potential, what other active areas of research are ongoing in seafloor hydrothermal systems? What is their relevance to astrobiology and the origin of life on Earth?

19:00 Ice-breaker

## ***Tuesday 4.10.16- Characterisation of deep-sea mineral resources***

9:00 - 10:00 **[L]** Results from ODP cruises drilling active hydrothermal systems in two very different tectonic environments: PACMANUS and Middle Valley. [NGU: Dr. Terje Bjerkgård].

The lecture will focus on the processes and formation of SMS deposits in different tectonic regimes as learned from experience from drilling active hydrothermal systems. The PACMANUS hydrothermal field (Papua New-Guinea) is in an extensional regime, in a back-arc basin, and hosted by felsic volcanics, whereas Middle Valley (offshore Canada) is in a sediment-filled, mid-ocean ridge graben structure, hosted by hemipelagic and turbiditic sediments underlain by mafic (basaltic) volcanics. The differences in anatomy of the systems, metal contents, textures and wall rock alteration are among the things that will be discussed.

10:00 – 11:00 **[L]** VMS deposits and their modern analogues seafloor hydrothermal system. [NGU: Dr. Terje Bjerkgård]

In the lecture we will compare ancient and modern sulphide deposits and the hydrothermal systems forming them. What can be learned from ancient deposits which can help us understand the modern systems and vice versa? Modern and ancient deposits in very different tectonic environments will be discussed with respect to anatomy and structures, size and metal contents, as well as the models of formation.

11:00 - 12:00 **[L]** Ore metals and minerals found in seafloor hydrothermal systems [CGB: Prof. Filipa Marques]

Sulfides contain ore metals of economic interest. In this lecture we will look into the mineralogy of sulfides and sulfates that are found in many seafloor hydrothermal systems and sulfide deposits. In order to portrait an hydrothermal system as a potential mineral resource one must first understand its mineralogical assemblage. Geological setting, temperature, pressure, the nature of host rocks amongst other factors, will influence the nature of seafloor hydrothermal systems and consequently their characteristic mineralogy.

12:00 - 13:00 Lunch break

13:00 - 14:00 **[L]** Nordic Subsea Sector, bringing industry and research together [GCE and DOF Subsea Subsea: Jon Hellevang]

14:00 - 16:00 **[L+P]** Deep Sea exploration techniques and tools: visit to the Ocean Laboratory [CGB: Prof. Rolf B. Pedersen]

### ***Wednesday 5.10.16- Exploration and Technology***

9:00 - 12:00 **[L+P]** Probabilistic resource assessment and its application on deep-sea massive sulfide deposits [NTNU: Prof. Steinar Ellefmo]

Different assessment methods and their input data used in mineral prospectivity analysis and quantitative resource estimation on a regional scale will be discussed. Emphasize will be put on how these methodologies have been applied in oil and gas exploration on the Norwegian shelf and in international exploration for onshore mineral deposits and how they can be applied to quantify the amount and associated uncertainty of undiscovered marine mineral resources.

12:00 - 13:00 Lunch break

13:00 - 16:00 **[L+P]** Technologies for deep sea mining [NTNU: Prof. Steinar Ellefmo]

Different mining technologies have been developed and tested since the 1970's. These technologies and their development will be described and links will be made to technologies used in modern oil and gas industry. Technologies planned to be used at the Solwara 1 project and necessary adjustments for more rough (weather) conditions will be presented and discussed.

### ***Thursday 6.10.16- Deep Sea Systems***

9:00 - 16:00 **[P]** Field Trip to a VMS deposit [CGB: Prof. Rolf B. Pedersen]

### ***Friday 7.10.16- Environment and Offshore Regulation***

9:00 - 10:00 **[L]** Icelandic legislation and regulations for offshore exploration and exploitation for non-energy mineral resources [Orkustofnun – National Energy Authority: Legal Adviser Hanna Björg Konráðsdóttir]

10:00 - 11:00 **[L]** Granting offshore licences in Iceland for non-energy mineral resources: Geological and environmental issues [Orkustofnun – National Energy Authority: Manager Mineral Resources Bryndís G. Róbertsdóttir]

11:00 - 12:00 **[L]** Arctic Deep Sea Mining: assessments, possible impacts, concerns, and necessary measures for protection and mitigation of marine ecosystems [to be confirmed]

12:00 - 13:00 Lunch break

13:00 - 15:00 **[L+P]** International Regulations for the Deep Sea Exploration and Exploitation [Norwegian Petroleum Directorate: Harald Brekke]